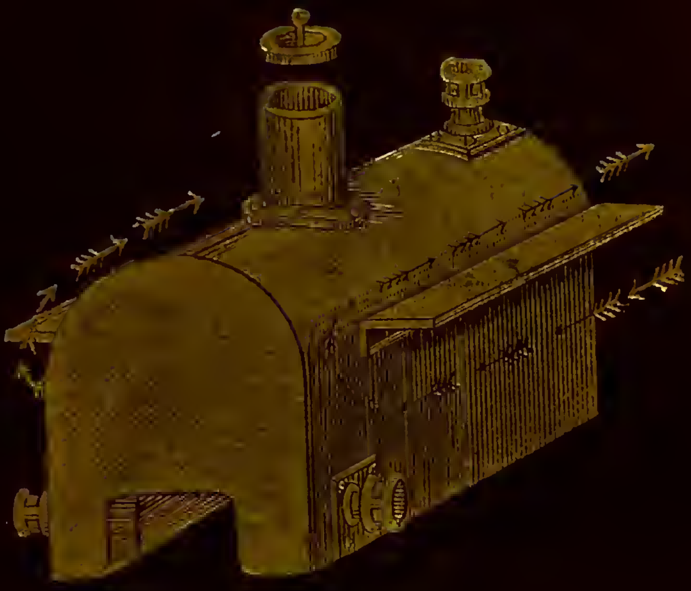

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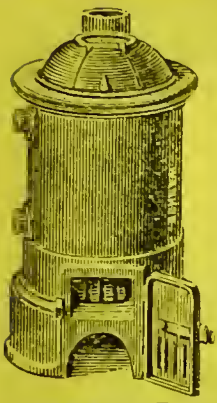

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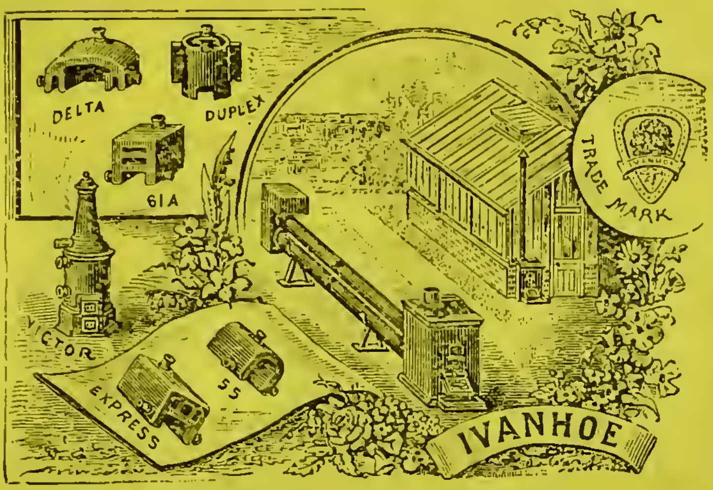

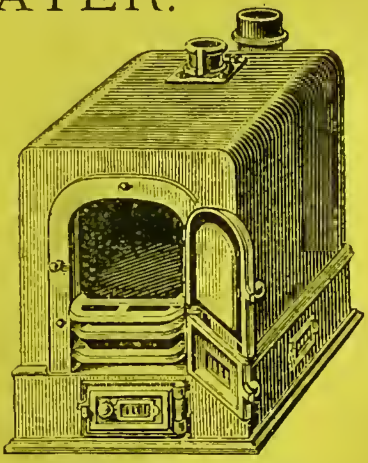

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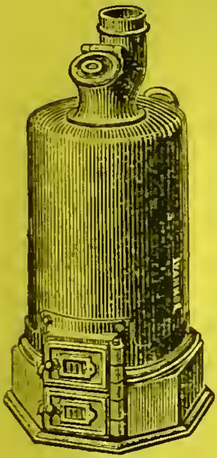

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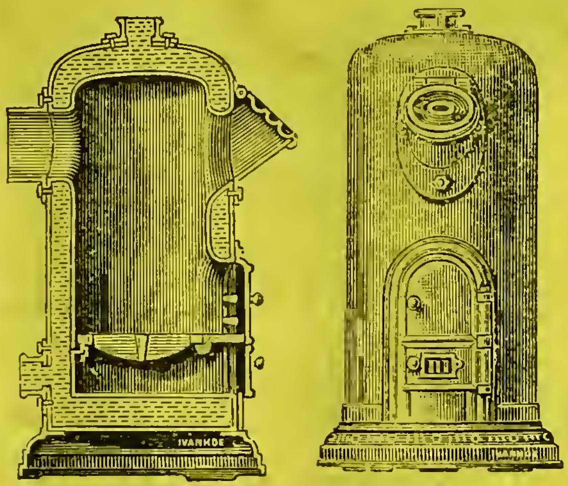

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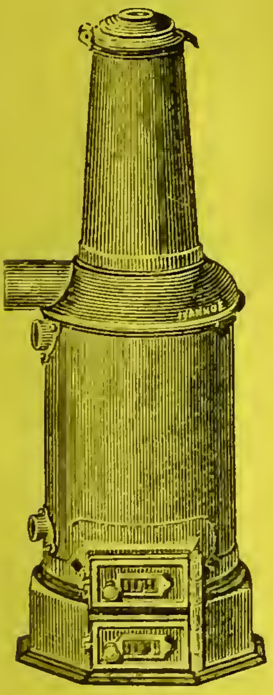

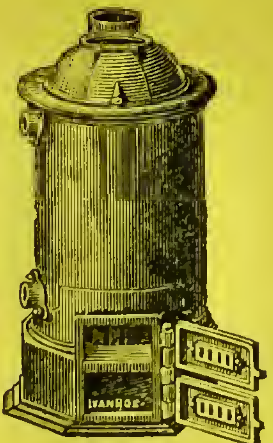

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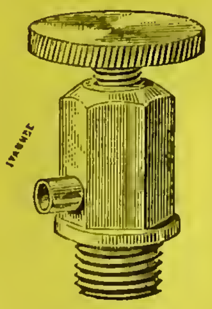

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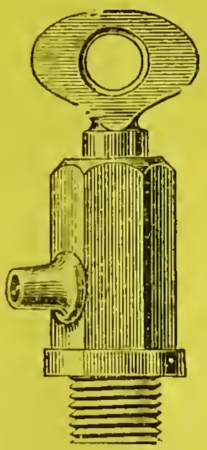

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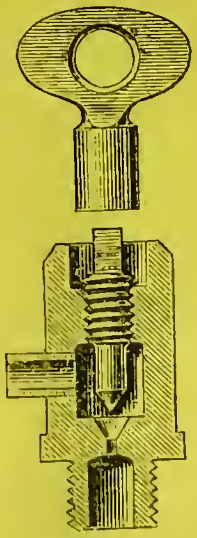

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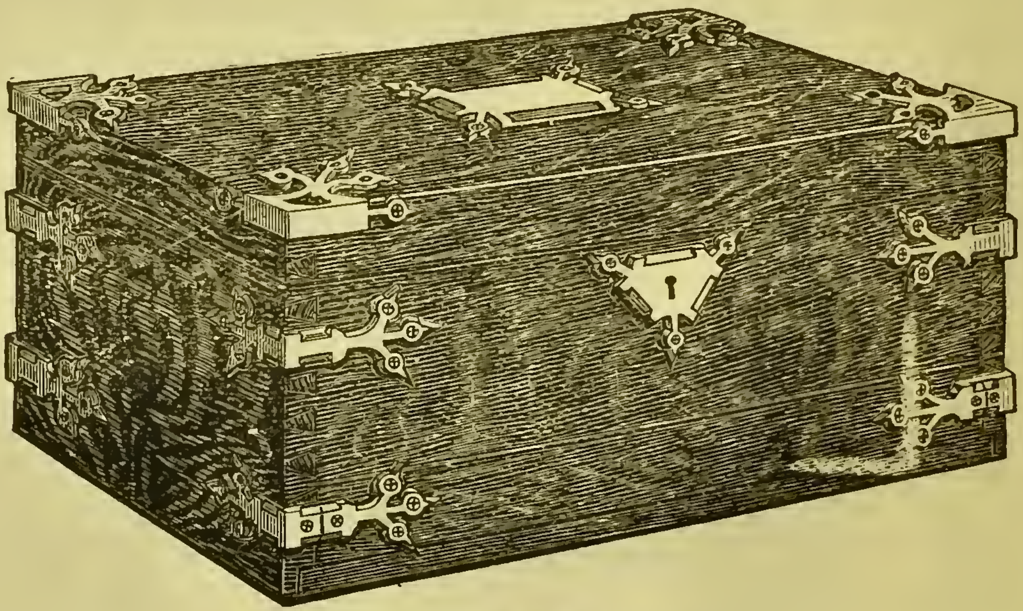

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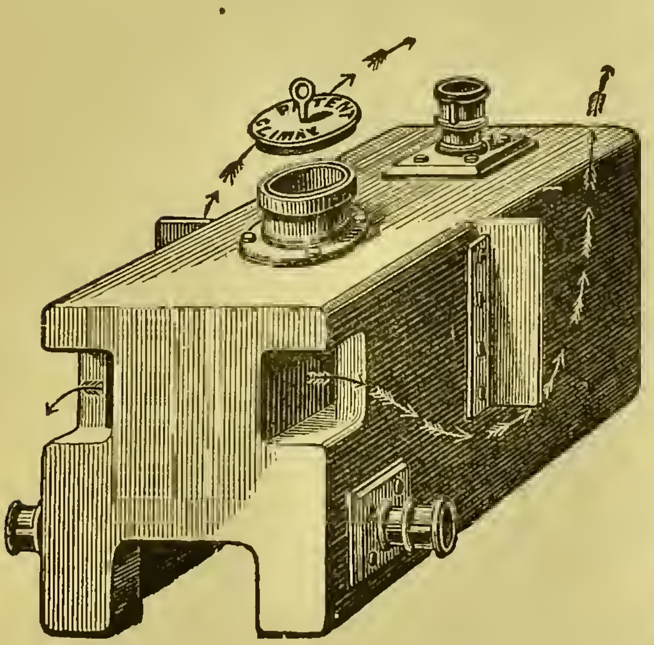

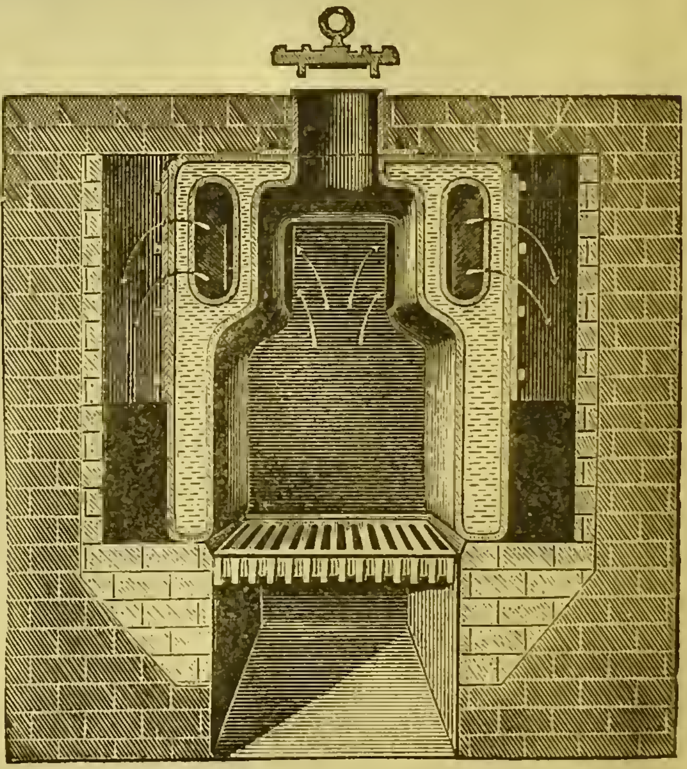

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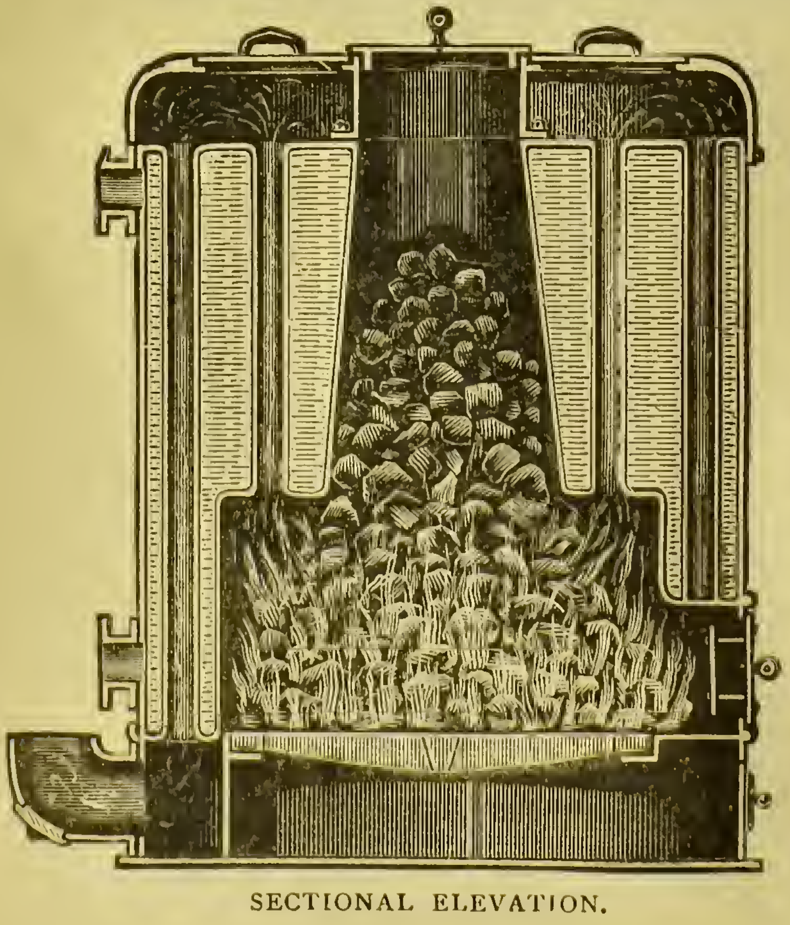

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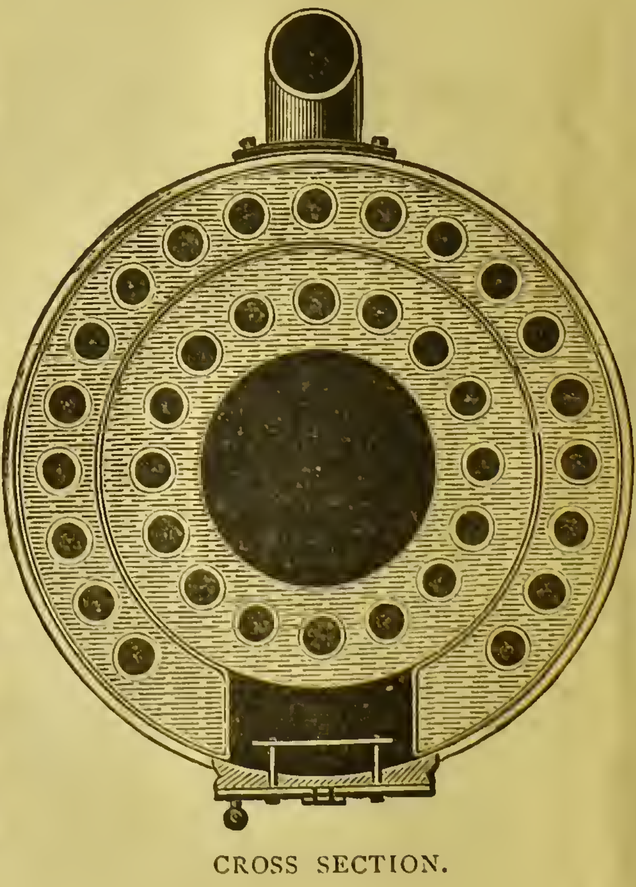

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A PRACTICAL TREATISE
UPON
WARMING BUILDINGS
BY HOT WATER
AND UPON
HEAT AND HEATING APPLIANCES IN GENERAL

WITH AN ENQUIRY RESPECTING VENTILATION,
THE CAUSE AND ACTION OF DRAUGHTS IN
CHIMNEYS OR FLUES, AND THE LAWS
RELATING TO COMBUSTION

By CHAS. HOOD, F.R.S., F.R.A.S., &c.

REWRITTEN BY
FREDERICK DYE
AUTHOR OF 'HOT WATER SUPPLY,' ETC. ETC.

THIRD NEW EDITION, FULLY REVISED TO DATE

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PREFACE

TO

THE THIRD NEW EDITION.

WHEN first undertaking the recompilation of Hood's deservedly popular and valued book, it was with a feeling that the information it already contained would scarcely bear revision, except that, during the years subsequent to his death, many new appliances and modified principles had been introduced and come into general practice. Since, however, the first new edition was published, in 1892, there has been a further and marked advance in hot water engineering, sufficiently so to make a complete revision necessary for this third edition, and several chapters have had to be almost entirely rewritten.

Undoubtedly the public, and those who influence the public, are becoming more appreciative of the advantages that heating by hot water has, for within the last few years work of this character has been in much greater demand than has ever been experienced in this country before. This, in turn, has stimulated the hot water engineer, and better still it has stimulated the makers of appliances, for although somewhat crude devices are passed in works carried out in public schools and similar institutions, it rests entirely with the manufacturer to make the work acceptable in good private residences.

The day cannot be far remote when the majority of residences of fair size will have a hot water heating plant in work that it taught, and leaned more towards the scientific aspect of the question than is suited for general reading.

Opportunity may be taken to afford Hood the highest praise for his labour and researches. When it is remembered that his book was first published in 1837, when the art of warming by hot water was little known and practised less, it is remarkable that the rules and tables he then laid down should still be universally followed, except that allowance has had to be made to balance his accurate experimental data with the less effective results we get in common practice.

FREDERICK DYE.

58 St. Paul's Churchyard,
London, E.C.

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WARMING BUILDINGS

BY

HOT WATER.

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HEAT.

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THE sensation produced when we approach or touch anything of a high temperature was, until a comparatively short time ago, attributed to the presence of an infinitely subtile material, matter or fluid (whatever one likes to designate it) that pervaded substances that had been acted upon in a manner to make them what we call "hot"; this delicate fluid being imponderable and, in fact, impalpable to all our senses except that of feeling. When the material assumed a redness from heat, it was not supposed that the fluid itself was thus made visible, but that it was merely an altered appearance of the substance due to the presence and condition of the fluid. The name given this material was Caloric (*calor*, heat) of the Material Theory.

Side by side with this belief was another which for some time did not receive so much favour, by some inexplicable cause, but which now is considered to be, and is recognised by all without exception, as the true cause of the phenomena under discussion.

By this latter theory we understand that heat is wholly and solely motion—nothing more and nothing less—a rapid movement of the small particles (molecules) of which all descriptions of matter are made up; the rapidity at which the particles move being the index to the temperature, so to speak; that is, the more rapid the movement the greater the heat felt, and *vice versâ.* This has received the title of the Kinetic (motion) Theory.

Great were the contests at the time that these two theories were approaching an equal footing, the followers of one having as many irrefutable arguments as the other; but Count Rumford, Sir Humphry Davy, and more recently Professor Tyndall, are chiefly responsible for the victory of the kinetic principle.

The first of these scientists received his chief impressions from noticing that in boring cannon the gun itself became heated, the shavings noticeably more so, and also the tool; and this heat was evolved and felt for however long a period the boring was continued. Sir Humphry Davy's chief or best known experiment was to cause a blunt steel tool to revolve at a high speed against the bottom of a metal cylinder, this cylinder being surrounded by another and the space between filled with water, and so long as the tool revolved the friction produced sensible heat, and the water attained a high temperature whether for an hour or days. It requires but little discernment now to see how opposed this is to the material theory, in which substances or bodies were supposed to have a capacity for so much hidden heat (that is, to hold or have room for a certain quantity of heat which did not manifest itself except under certain conditions). For these experiments showed that two very small pieces of metal, if kept in friction one against the other, were capable of giving out heat for an almost endless period, or until they were worn away. Then again, with our most precise and delicate appliances, it has been impossible to discover the slightest increase in heaviness in a body after it has been heated, yet the lightest gases and elements known to us have a very sensible weight.

Heat transmits or manifests itself to our sense of feeling in three ways, viz. by—

1. Conduction.
2. Radiation.
3. Convection.

All these three methods intimately concern the art of heating by hot water, and a knowledge of them is accountable for the majority of the improved appliances introduced.

1. CONDUCTION OF HEAT.

This is the mode by which heat is transferred through or about a material or body; but its effect is chiefly noticed with solids, some of which possess great powers of conductivity, although fluids (both liquids and gases) possess this property to a limited extent.

In discussing hot-water work it is not with the conductive powers of fluids that we have to deal, for, as just mentioned, the property is manifested to such a limited degree as to be useless for practical purposes, excepting when it is desired to *prevent* loss or transference of heat. Fluids come under the heading of poor conductors of heat, of which we shall show the utility presently.

Water is a good absorber of heat, and as a generally applicable rule we may consider that anything that absorbs heat readily is just as willing to give it up again. Consequently, in water we have an exceedingly cheap and available material in the greatest abundance, admirably suited for the absorption and dispersion of heat needed in hot-water work. But these two qualities which it possesses are by no means all that is necessary for a successful apparatus. We cannot have the heat direct from the water itself, owing to the necessity of enclosing it in some form of vessel or container (piping); and if the material of this container is not a good conductor of heat, all the good qualities of the water and other parts of the apparatus are rendered *nil.* And further than this, the materials must not only possess successful conductive powers, but must also have another quality, which will be found under the heading of Radiation.

COMPARATIVE CONDUCTIVE POWERS OF SUBSTANCES.

(Wiedemann and Franz.)

	Conductivity.
Silver	100·0
Copper	73·6
Brass	23·6
Iron	11·9
Lead	8·5
German silver	6·0

(Despretz.)

Silver	97·30
Copper	89·82
Brass	75·20
Cast iron	56·90
Wrought iron	37·43
Lead	17·96
Marble	2·36
Firebrick	1·14
Water	0·90

An appreciable difference exists between these two tables, as will be seen at a glance, although the different substances follow in rotation alike in both cases; but it is worth noting that H. G. Madan, in his excellent work upon Heat (1889), follows the former table closely, his figures standing as follows, silver being taken as the standard = 100.

(Madan.)

	Conductivity.
Silver	100·00
Copper	74·00
Iron	12·00
Lead	8·50
Marble	0·15
Glass	0·05
Wood	0·01

Hood quotes the second (Despretz's) table. When a material is subjected to heat it is supposed that the particles or molecules (of which the substance is built up) nearest the source of heat are set in motion, this movement being of a revolving character similar to what we have on a vast scale in our planetary system, particles rotating and travelling round and about one another. (This is only hypothesis, as the motion has never been detected by the most careful microscopic treatment.) As the temperature increases, the rate of motion is increased in like ratio ; but the mere increase and decrease of motion and proportionate increase and decrease of temperature do not accelerate or retard conduction in any important way. The latter effect is due to a property possessed in a greater or less degree by the material itself, which either permits of a free motion of its particles and allows of a ready *transference of the motion* of heat, or the reverse.

For the present purpose we may consider that the property of conduction only applies to the metal composing the boiler plates and that of which the pipes or heat-diffusing appliances are made. Conduction cannot be said to apply to the fire round the boiler or the water within it, nor the air outside the pipes or the water within them. It only applies to the material that separates the fire from the water, or the water from the air, respectively. If we could apply the fire heat directly to the water and transfer the heat from the heated water without the intervention of any material, however good its conductive power may be, we should get much better results: that is to say, by a less consumption of fuel and in less time.

There is not the least doubt that heating by hot water would never have attained its present popularity if the materials so well suited to the purpose were not so cheap and easily obtained, for in cast iron we have a substance possessing ample strength, easy of adaptation as to form, size, &c., by the common process of casting, cheapness due to abundance, and what is more necessary, a good conductive power.

Cast iron is of greater conductivity than wrought iron by a considerable degree, and what is objectionable in wrought pipes (even if of as little cost) is that its greatest conductive power lies with the grain or fibre, and not across it in the way it would be of the greatest use for this purpose.

It is difficult to say which of the three modes of conveying heat is of the greatest importance in hot-water work, for each is most intimately concerned in the success or non-success of the work. If the boiler or pipes were constructed of any substance possessing a low conductive power there would be an almost impassable barrier introduced at once, the heat being closely imprisoned within the apparatus, although ready in every sense of the word to dissipate itself, if the circumstances were favourable.

Poor conductors of heat enter into the construction of nearly every apparatus that is erected, in some form or another, as it is not sufficient that we merely transfer *some portion* of the heat of combustion to the water, and subsequently to the place to be heated. We have to carefully consider the question of economy in fuel and labour, and consequent wear and tear, and a hot-water engineer's good reputation is frequently based upon his success in this particular. Indeed, it is no uncommon thing for an apparatus to be either partially or totally unsuccessful, owing to its dissipating heat where the heat has no valuable use.

First may be mentioned the great use made of firebricks in the construction of the flues surrounding the boiler (if the boiler is not an independent one), this material having the double advantage of poor conductivity and a refractory nature, so that although a flue surrounding a boiler is of course bounded on two sides, one by the boiler and one by firebrick, it is only on the boiler side that absorption of heat takes place to any material extent. And the peculiar nature of the clay of which firebricks are made makes them well suited for the purpose, owing to their good wearing properties under the influence of heat.

An important instance of the utility of a poor heat-conducting material is in covering the main service pipes and the branches of an apparatus, at all those points where heat is not to be dissipated from them. This occurs in horticultural works as well as in buildings, though in the former the boiler is usually so placed that the pipes commence to do useful work immediately they leave it. In buildings the mains, sub-mains, and branches, extend through cellars and places, for long distances, to reach the points where warmth is required, and unless covered with some poor heat conductor the water loses a deal of warmth between the boiler and its actual work. By preventing this loss the boiler has less work to do, and does it in less time and more effectually, besides using less fuel. Loss of heat in this way always seems very unreasonable.

Another important instance of the kind is when the boiler is of the independent description requiring no brick setting, these boilers being most liable to loss of heat in a way that is opposed to good results. It will be noticed that with all independent boilers, including those illustrated in this treatise, the whole outer surface, both of the portion that contains water and of parts constituting the fire-box, is fully exposed to the air and all its influences. In an actual experiment made with a vertical dome-topped boiler, it was found that a coil situated a short distance away took one-fourth longer time to heat when the boiler was exposed, than when it was covered with a poor conducting compound. It will be readily understood how quickly the heat is transferred from the fire to the outer surface of the boiler, and the information upon radiation and convection will show clearly how soon the heat is disposed of when once it has reached this point.

For some obscure reason the word "non-conductor" has become quite common, through heedlessness probably, as there is no such thing as a non-conductor of heat, although very many substances rank as exceedingly poor conductors, and on this account answer general purposes almost as well as a non-conductor would. The commercial materials used for encasing hot-water pipes to prevent loss of heat are hair and wool felt, silicate cotton (slag wool), asbestos, sawdust and certain patented compositions, and the following tables will give a clear idea as to what an almost impassable barrier some of the substances are.

TABLE OF HEAT CONDUCTIVITY.

(Box.)

Eider down	·314
Felt	·323
Sawdust	·523
Firwood	·748
Coal ashes	1·29
Plaster	3·86
Stone	13·68
Marble (fine)	28·00
Iron	233·00

TABLE OF RESISTANCE TO CONDUCTIVITY.

(Thurston.)

Felt	1000
Silicate cotton	·832
Sawdust	·686
Pinewood	·553
Gas-house carbon	·570
Asbestos	·363
Coal ashes	·343

There is a peculiar property related to the conductive power of iron now to be considered, as its application is becoming more and more general. This has been very correctly named "diffusivity," meaning the power that iron has of diffusing heat over a large area of its substance, though only receiving heat at one point. It is simply another name for conduction, but the result bears a different application. If we take a hot-water pipe and charge it with water at a temperature of, say 180°, the heat at the outer surface will bear a close relation to these figures; but if we add a number of gills or feathers to the pipe, as at Fig. 1, the heat will instantly diffuse itself into these plates, and the result will be that instead of a small area at a high temperature, we shall get a greater area at a lower temperature. That is to say, we shall get a greater radiating surface but giving off cooler rays of heat, and a greater surface for air contact, but the air will be heated to a less extent. We do not expect to get a higher aggregate temperature, as in both cases the results are only brought about by a certain quantity of water

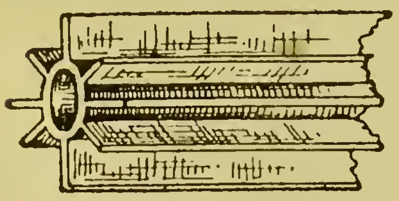

Fig. 1.

at 180°, but by this means we are able to get better results under certain conditions. In indirect work, which affords the required heat wholly by imparting warmth to new air passing into the building, the humidity of the air is less affected and no noticeable dryness to the atmosphere can be detected. It is, however, in stove work, and heating air by stoves, that this property of heat diffusion in metal gives the most marked beneficial results.

When treating open fire-grates we shall speak of the *disadvantages* experienced by the good conductive power of iron, and the various means of obviating the difficulty.

RADIATION OF HEAT.

To clearly grasp the existing theory of radiant heat (*radio,* to emit beams or rays) we have to understand that there exists around us, in every conceivable space, an infinitely thin and subtile medium, which is termed the *ether* (or the interstellar medium). It is quite independent of the atmospheric air, or, we may say, is mixed with it, and this medium is the means by which radiated heat, as also light, is transferred or conveyed from a hot body to surrounding objects. *Radiant heat is therefore the motion of heat transmitted to the ether, which motion is carried or propagated in the form of waves in straight lines from the source of heat.*

It is not at all necessary that air be present to effect the phenomena of radiation, for if we suspend a thermometer in a vacuum and apply heat outside, or place a heated substance in the vacuum and the thermometer outside, or place both in a vacuum, we find that the transmission of radiant heat is still manifested. Consequently we must believe that this ethereal medium is of a totally different character to air or gases, as it cannot, apparently, be withdrawn from a vessel in the manner we should exhaust it of air.

We have already mentioned that the fact of a material conducting heat satisfactorily, as iron does, is not sufficient to ensure success to a hot-water apparatus, for the simple reason that the heat brought to the surface of the pipes only, is practically useless. To benefit by the heat we must have it striking against us, and surrounding objects, in the form of radiant rays, and it must also part with its heat to the surrounding air. Silver pipes, as mentioned, would give the best possible results so far as conduction is concerned, but a highly polished silver surface has very low radiating qualities, consequently this costly material would not, with its excellent conductive power, answer so well as plain black cast iron, as the following table will show :—

RADIATING AND ABSORBING POWERS OF SUBSTANCES.

(The *absorbing* and *radiating* powers of materials are equal, but their *reflecting* powers are in exact inverse ratio.)

(Pouillet.)	Radiating and Absorbing Power.
Lampblack	100
White lead	100
Glass	90
Cast iron, polished	25
Wrought iron	23
Zinc, polished	19
Steel ,,	17
Brass, roughly polished	11
Brass, highly ,,	7
Copper, either cast or deposited on iron	7
Silver, highly polished, either cast or hammered	3
(Leslie.)	
Lampblack	100
Water (by estimate)	100
Glass	90
Plumbago	75
Tarnished lead	45
Clean lead	19
Silver and copper	12

Neither of these tables gives a comparative figure for plain cast iron (unpolished), but from results obtained in practice this should stand at about 60, if the outer surface is untouched, i.e. having its own natural coating of oxide.

From these tables it will be conspicuously noticed that polished metals are bad radiators, and on this account it is that kettles, urns, and the copper cylinders sometimes used in hot-water supply apparatus are, or should be, kept polished, to prevent loss of heat by radiation. *The radiating power of a body, however, is not due to its material substance, but to the nature of the outer film or skin;* so that if we were to coat a bad radiating but good conducting material with lampblack, we should get the best possible results. For example, silver has the highest conducting power, but the lowest degree of radiation; but coat a silver pipe with lampblack, and we have the highest conceivable success. And the rougher the coating of black the greater the radiation, for a rough material presents a greater surface than a smooth one, and radiant heat (the dark rays) *seems* to leave a rough surface (which really consists of a great number of minute points) more freely than a smooth one.

Lampblack is supposed to have no reflective power whatever, and consequently it is classed as a *perfect* radiator—at least as perfect as any known at present. This has led to a belief that colour materially affects radiation of heat, which is correct so far as regards rays of heat that proceed from a luminous body, these standing in order from white to black, the lightest radiating the least, and *vice versâ.* But this has no interest to the subject being treated, as we have only to deal with radiation from non-luminous bodies, and colour makes no difference whatever to the free radiation of dark rays of heat. This brings us to consider what is the best material to coat the coils and pipes of a hot-water apparatus with. It must be noted that the table of radiating powers given only applies to dark rays, that is, rays of heat proceeding from substances below about 500°.

Lampblack is doubtless the best of all materials to coat coils and pipes with, but this has an objection in the fact that it does not increase the sightly appearance of an object. Recourse is therefore had to paint, which fortunately possesses radiating powers very nearly equal to lampblack; and for rays of heat proceeding from non-luminous bodies, white paint will give about as good results as black, or any intermediate colour. Consequently, if we use the improved form of radiating coils (of which we shall speak fully presently) in a living-room, we are enabled to colour them to suit the surrounding decorations without any prejudicial effect upon their radiating efficiency. Two which the writer had erected in a drawing-room, and coloured ivory and gold, with marble tops, were eminently successful, both for efficiency and good appearance.

These ornamental coils or radiators are frequently bronzed for the sake of good appearance, and they act very fairly; but for radiating power preference should certainly be given to paint, as the bronze, whether copper or an alloy like brass, is composed of poor radiating materials, as well as being of a polished metallic nature.

A thick film of oil stands at ·59 in the scale of radiating substances with lampblack at 100, and as the majority of metallic oxides (which go with oil to make paint) are good radiators, a coating of such a mixture is very satisfactory.

It will be seen from the table that glass is a good radiator of heat, but it is a material that cannot be put to good practical use, owing to its low conductive power. Although capable of radiating or projecting heat successfully from its surface, we should not get the heat transferred through its substance with sufficient rapidity for practical purposes.

We have at present only spoken of radiant energy as existing at the extreme outer surface of the radiating media, and have now to consider how the agreeable effect of the heat is experienced by the body. First, it is to be understood that radiant heat does not (so far as this subject is concerned) increase the temperature of the atmospheric air. It has been commonly thought that the heat radiated from a bright fire is warming the air, but this supposition can be disposed of by placing two thermometers a few feet from the front of the fire, one facing and one with its back to the source of heat, and noticing the difference of temperature, although the same air surrounds both. But there is a more convincing and irrefutable proof of this in the fact that although on a summer's day the air might be warm near the earth, yet if we left the earth—in a balloon for instance—we should find the air get colder and colder as the distance increased. At a high elevation a thermometer will register a freezing temperature, *and yet all this time we should be getting nearer and nearer to the sun, which might be shining brightly all the while.* Radiant energy is felt in the form of heat on all bodies, our own bodies included, and air is heated by coming in *contact* with objects that have been heated. But in the case of the earth, we who are upon its surface have the benefit of the sun's heat *agreeably* transmitted to us owing to the presence of water vapour in the atmosphere, which fulfils two exceedingly beneficial purposes without which existence would be quite impossible.

Now, water vapour is a very great absorber of heat, and in this instance it firstly tempers the fierce heat of the sun that is radiated upon us, and secondly it effectually prevents the instantaneous loss of heat by re-radiation from the earth's surface and the objects upon it, which would take place if the water vapour were absent. If our atmosphere was what we may call pure, that is, free from the admixture of foreign substances, water vapour in particular, the presence of the sun would cause a really scorching heat to be felt, and its absence would be instantly noticeable by the loss of heat and a most intensely bitter cold. As we get away from the earth's surface the atmosphere becomes less humid, and the sun's heat is felt and lost almost at the same instant, the air remaining excessively cold and robbing us of heat by convection (as will be understood directly) at a great rate.

The peculiarity possessed by the atmosphere in not absorbing radiant heat (by which it would be made intolerably hot) is of particular benefit to mankind, whose nature is specially adapted to profit by it. Indeed it must be noticeable to every one that we require and are rendered comfortable by a much higher temperature for our bodies than for the air we breathe. This is evinced by the pleasure most people feel in breathing the sharp air of a fine winter's day, provided the body is well clothed and so kept at a good heat.

This naturally leads us to consider which form or method of heating is best suited to fulfil these natural and consequently most desirable conditions. Although each system will be treated fully hereafter, it may be mentioned that the methods are practically confined to four only, viz. open fires (radiant heat and air heated by contact with warmed objects); hot-water and steam pipes (radiant heat and air heated by contact with the pipes and by warmed objects); stoves (same as hot-water pipes, but with different and less pleasant results); hot air (air heated by contact with hot bodies and conveyed where required by pipes or conduits, and some radiant heat from bodies warmed by the air).

Radiant energy is projected from the source of heat in the direction of a straight line, but its motion has been likened to a series of waves which continue in one direction irrespective of other influences. As Madan says, "like the waves on water pursuing their course uninterrupted by tides and other influences." This motion—or it had better be called heat—loses its intensity very quickly as it leaves its source; not that we may consider the heat itself to be lost, but it quickly diffuses itself over a wide area. Thus it is felt over a larger space but at a lower temperature, and there is no objection to this, for we are thus enabled to heat a large space from one source of heat. As already mentioned, these rays pass through the atmosphere without affecting it, and their effect is only experienced on surrounding objects. Thus, in a room, the walls, furniture and other objects receive the heat which impinges upon them, and they in their turn re-radiate the heat in various directions, to various extents, depending upon their radiating power and other properties. So that when we stand in a part of the room where the rays from the fire do not directly strike us we still feel an equable heat (provided we are not near any rapid conductor of heat or near a window where a cold down-current nearly always exists), owing to the dark rays of heat from the surroundings being projected in all directions. But immediately we get near the fire and obstruct some of the rays that come directly from it, we feel hotter on the side nearest the source of heat than we do on the side removed from it, owing to the greater intensity of that which we receive from the fire than that which we receive from the warmed objects the other side. A very good illustration that heat travels in straight lines, is to hold any object in front of us as we face the fire and notice how instantly the heat is cut off, and a minute observation made at the moment would show that a greater heat would be felt from the objects at the back from which we have not shielded ourselves. If radiant heat did not travel in straight lines a sunshade or awning would be very useless things.

It has been very pertinently pointed out that this fluid theory of radiant heat, i. e. that radiant energy is transmitted by a subtile ether, existing in an intermingled state with the atmosphere, and beyond the atmosphere (to account for the sun's rays being transmitted to the earth), may at some time be exploded like the fluid or material theory of heat itself (see p. 9). This is practically the last of the fluid theories of heat, and is founded upon mere conjecture, as the fluid itself has never been detected, neither by weight nor other experiments. And what may be considered as rather a doubtful feature, is that radiation proceeds about as well in a vacuum as in the air, showing that although we can exhaust the receiver of a good air-pump almost perfectly, we do not apparently abstract this ether, notwithstanding that every other known fluid can be withdrawn readily.

In hot-water work it is only the dark rays of heat that have to be considered, as no part of an apparatus, even upon the high-pressure system, is supposed to exceed about 350° temperature at the radiating surface, and is consequently far from being luminous.

The surface of a boiler nearest the fire gathers heat in several distinct ways, viz. by radiation from the glowing mass, by contact with the glowing mass, which we might call absorption, and by contact of heated gases. Of course the greatest effect is brought about by radiation from, and contact with, the glowing fuel, which gives the water every opportunity to manifest its rapid power of absorption. Flame needs no consideration, as coke is the fuel regularly used (except at some special time, or under some special circumstances), but the hot gases evolved, which it is understood include the highly heated products of combustion, are an element of some importance, as the flues which are carried round and about a boiler have no incandescent fuel within them, and the surfaces within these flues receive heat from the hot gaseous products only.

Heated gases, it will be found, only do effective work in the boiler flues by coming into actual contact with the surfaces, which surfaces, if of an absorptive nature, take up some of their heat, and if by any means the heated products are able to escape without touching the surfaces in question, decidedly less good results will be obtained. It is peculiar to note that these gases manifest to a great extent a property which is very noticeable with flame, and that is to avoid coming into actual contact with surfaces if there is room and a possible way to avoid so doing. So that if we surround a boiler with 31
flues larger than a recognised efficient size, very little heat will be gained from what passes through them ; yet, on the other hand, we cannot successfully cramp the flues beyond a reasonable limit, as will be shown presently.

CONVECTION.

A knowledge of the two subjects, Conduction and Radiation, is of considerable necessity and interest in studying any mode of heating ; but where we employ water as the medium for the transmission of heat, the present subject, viz. convection, possesses greater interest than all, and a knowledge of it is absolutely necessary for the proper planning and carrying out such work.

Convection (from *conveho*, to carry up) is described as "*the act of conveying heat by the ascent of heated particles in a* *gas or liquid.*" Water and gases, in fact all fluids, are composed of one or more elements existing in the state of a mass of exceedingly minute particles, which are termed molecules, these particles having no cohesive or adhesive properties. In fact the commonly accepted notion is that a distinct repelling influence exists, which causes the particles, as of water and particularly of gases, to spread in all directions when unconfined. We might compare a mass of water to a mass of exceedingly fine sand, except for the property just explained ; for although the particles of sand are all free and quite independent of one another, like the particles of a mass of water, yet we can have a piled-up heap of the former, but no one ever saw a heap of the latter. One reason accounting for the heaping of sand, is that the friction amongst the particles, owing to their irregular shape, helps and is in fact the chief cause of their supporting one another. No suggestion has been made as to the shape of water molecules, but it would be inferred that they must be spherical, which would then account greatly for their very perfect mobility. If we took, say, a basket of small coke (an irregular shaped material) and a basket of glass balls, and emptied them on the ground, there is no doubt about the balls acting very much like water would do, viz. spread out in all directions, but the coke would not do this.

Fluids, however, both liquid and gaseous, possess the property of mobility in a most marked degree. The particles have the most free and independent motion possible to conceive, not manifesting the faintest sign of friction between themselves, and when water is agitated the particles glide over and under and around one another without interruption or resistance in the slightest degree. On this account, i.e. the absence of friction, water would want an enormous amount of agitation to raise its temperature perceptibly.

We may therefore consider a body of water when undisturbed and of a uniform low temperature, to be a mass of minute particles, all stationary, yet free to move by the slightest cause ; and if we take a glass vessel—a large tumbler or an ordinary jar will do—we can quickly investigate and become acquainted with the exact action of Convection. First, it is necessary to obtain a substance that will be visible in water (for water is invisible) without giving erratic results, and nothing is better than *amber* for this purpose, if in the state of very fine powder, as the specific gravity of this material is 1·080 with water at 1·000. Or the finest sawdust of some moderately heavy woods answers very fairly.* If we apply heat to the bottom of a vessel charged with water having this dust material in it, we shall notice almost immediately that some of the particles are propelled upwards, and as the particles leave the bottom and lower part of the vessel, other particles will be noticed travelling down from the upper part towards the bottom to take the place of those that have ascended.

The exact action is as follows: the particles or molecules of water in contact with the bottom of the vessel are stationary before the heat is applied, but immediately heat is transferred to them they expand in bulk and are thus rendered lighter (bulk for bulk) than their fellow particles, with the consequence that they immediately begin to rise like any substance would that is lighter than its equal bulk of water. We may consider that these heated and lightened particles of water (although still of the same composition of water) act like a foreign lighter material such as cork, and insist upon rising to the highest possible point, until they have lost some of their heat and so become of less bulk again. As these particles rise they carry up the particles of amber with them, by which means the action of the water is illustrated.

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* I have tried amber several times, and also mahogany dust; the gravity of amber, however, either varies very greatly, or else we have a far greater number of imitations of this article than we are apt to suppose, and it is sometimes necessary to discard two or three pieces owing to their uselessness for this purpose. With mahogany dust there is very little objection; it has a tendency to *sink to the bottom* (the greater portion of it), but the ascending current of water carries the particles up, which is exactly suited to the requirements. A substance that wholly floats at the top of the water would not answer the purpose at all. It has been stated that charcoal dust answers the purpose.

After but a very short time a steady circulation will be found to have set in, as at Fig. 2,* and this circulation will continue so long as heat is applied to the bottom or lower part of the vessel. It is doubtful if this circulation would ever cease while heat is applied, as although we may suppose that the water would attain a uniform temperature eventually, this is not the case with a heating apparatus. With this latter a reduction in temperature takes place very soon after the water leaves the boiler, owing to the ready radiation of heat both by water and iron, as already explained, and from the contact of cold air. Consequently there is always a difference, more or less great, between the temperature of the water leaving and that entering the boiler; the difference in temperature meaning, of course, difference in bulk for weight. This is the simple explanation of Convection as applied to water, but in a later chapter the subject will have to be dealt with more fully.

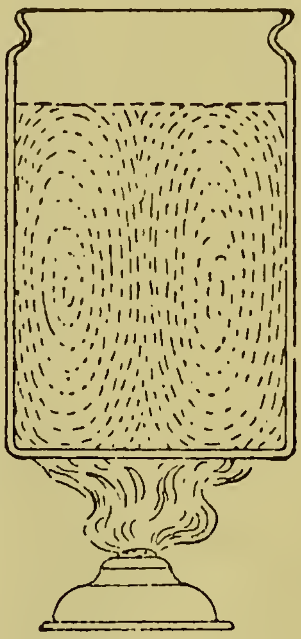

Fig. 2.

There is no doubt that the rapid heating of water and gases was originally attributed to Conduction—a very reasonable deduction indeed, as it is this phenomenon that accounts for the transference of heat throughout the mass of all solids. But in solids we can obtain a transference of heat to the portion furthest removed from its source, whether the heat be applied to the top, bottom or sides, which is not the case with fluids, as can be simply tested with the glass vessel just referred to. If this vessel be filled with cold water and a gas flame be applied to the top, it would be found to take a very great time before the least trace of heat reached the lower part, showing, as has been conclusively proved, that water does not conduct heat at all willingly, and it has been classed as one of the poorest conductors. If, on the other hand, we took a vessel of hot water and placed a very cold substance at the top of it, a circulation would be noticed at once, as in this case we simply reverse the action of the convection currents. The cooled particles being rendered heavier (bulk for bulk) than the hot ones, they instantly sink to the bottom and hot ones ascend to take their place.

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* It is very interesting to watch this phenomenon, its action is so regular, and the particles of solid matter (amber or wood) spring up from the bottom and travel round apparently without any reason or cause, yet in such a regular and uniform manner. It is also interesting to look at the action *from the top*, that is through the upper exposed surface of the water, the particles rising and falling like a stream of animalcula, all travelling in one recognised direction. A peculiar result that will be noticed is, that notwithstanding the disturbance, i.e. the circulation of the water, the upper surface is *undisturbed and perfectly motionless.* Never was there a better illustration of the upper layer of molecules in a vessel of water forming *a skin* to the contents. As the water gains in temperature the bottom of the vessel will get encrusted (inside) with minute air-bubbles, showing how the aeration of the water is disposed of, and rendering water that has been heated so flat and unpalatable. If mahogany dust is used the water will become impregnated with some of the brown colouring matter of the wood, but this is not objectionable.

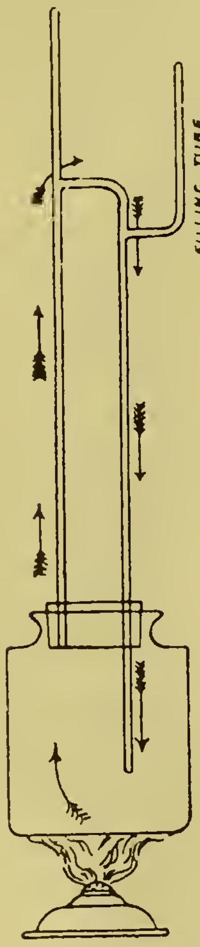

Fig. 3.

It will be seen that the vessel just referred to only illustrates the action of the water in an open boiler, and although we may look upon a system of pipes from which heat is radiated as mere extensions or continuations of the boiler, the way in which the hot water is conveyed (or conveys itself) into them needs explanation.

If we construct an apparatus as at Fig. 3, which consists of a bottle with two glass tubes passing through a tight-fitting cork stopper (one reaching say three-fourths of the way to the bottom, and the other not projecting inside in the least degree, for reasons to be presently explained), and carry these tubes something like the illustration, we shall have a model apparatus of simple form, which will in its action explain everything very clearly.* When the heat is applied, the circulation will set in almost instantly, and it will set in at all parts, that is to say, it will not be confined to the boiler, but will, at

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* The writer has adopted very humble materials in illustrating this apparatus, but they possess the advantage of acting with as great certainty

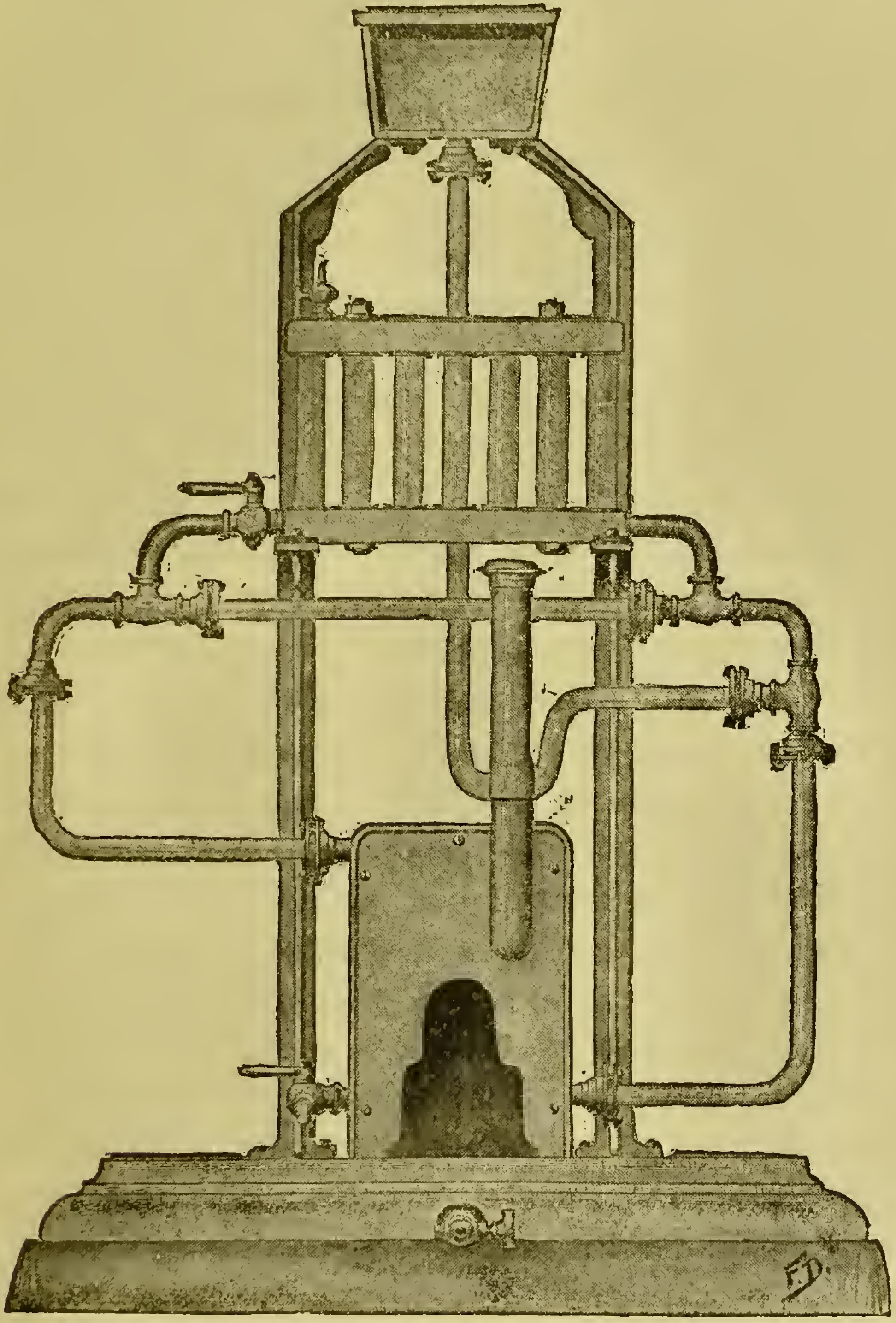

Fig. 4.

as an elaborately constructed model, and as the whole is glass the result can be noted with greater accuracy than with any metal fittings. But if any one proposes investigating the matter thoroughly, or to demonstrate the action to a class of students, a well-equipped model, as Fig. 4, can be had. This model (designed by the author) stands about 2 feet high, and shows a coil of vertical pipes (a radiator in fact), connected up on the "one pipe" system. The illustration is from the catalogue of A. B. Coleman, 263 Albert Road, Aston, Birmingham.

the first indication of a movement, be seen travelling along the pipes in the direction indicated by the arrows. It is hardly sufficient to say that the motion is brought about by the fact that heated water is lighter than cold of the same bulk. It is really the other way about, as the phenomenon is wholly due to gravity, that is, the cold water being heavier than the hot, which, although a trifling distinction, has a considerable difference for the purposes of this discussion.

The cold water having greater specific gravity than the hot, has a tendency to sink and find the lowest possible point by reason of its superior weight, so that when a particle of water becomes heated and rarefied in the slightest degree, it is instantly pushed away, so to speak, by its surrounding fellows whose weight is now superior and able to displace the lighter mass. It can be seen that hot water has no tendency to rise whatever without being compelled to do so by a superior force. If a vessel is filled with hot water, no part of it will raise itself beyond its natural level ; consequently the particles of warmed water that rise and constitute a convection current, take up this motion entirely by reason of their being urged in that direction by a crowd of heavier fellows all jostling and making their way to the lowest point by their greater weight or gravity. To use the expression attributed to Dr. Balfour Stewart, "Were there no gravity there could be no convection ; were it not for gravity it would be of no consequence what part of a vessel we heated, the effect of the heating would be always the same."

This is a slight digression, but it is to make it more clear why the circulation or convection current sets up in all parts of an apparatus at once, instead of locally to the source of heat, as some might possibly suppose. When the layer of particles nearest the source of heat are rarefied and pushed up by the heavier particles surrounding them, this movement is, as a matter of course (owing to the inelasticity of water), transmitted from the highest point, in the same way that there would be an instant movement from top to bottom of a tube or vessel of water if we withdrew some of its contents at the bottom. Consequently, in an apparatus as at Fig. 3, we shall find that the down and up flow will occur simultaneously from the highest to the lowest point in the circulating pipes, and the result is the same whether the erection be large or small, simple or complex, provided its principle is correct.

This is the result with a glass apparatus; with one of metal a little different conclusion might be arrived at, for although the heated particles are travelling up one of the pipes (the "flow" pipe), no heat will be felt externally for a little while, owing to its being absorbed in many ways, and we naturally cannot expect to have warmth from the outer surface until everything is warmed within. This is one instance in which model apparatus of glass tubes shows quite different results to those of an apparatus of iron pipes. With the latter, we do not feel any heat at the pipes for a little time, and this has led to the belief that the water circulates in the boiler for a certain period before any movement occurs in the pipes. With iron pipes there is nothing to show that the water is in swift motion within them.

No precise table can be laid down to indicate the speed of convection currents, owing to their being varied by so many different incidental circumstances, but the speed can be theoretically calculated by a rule that will be given in the next chapter. However, it may be considered that no liquid exists that will give better results than water, owing to its perfect mobility, and to the fact that not the slightest degree of coagulation takes place however much it may be used over and over again. And it is a material that can be obtained readily, and practically without cost, wherever the apparatus happens to be situated.

Many attempts have been made to utilise other liquids with the view of getting a higher temperature, and so obtain equal results with less pipe, &c., but at present nothing very satisfactory has been done, owing chiefly to the fluids which boil at a greater heat than water being of a more viscid or less mobile nature, such as a saturated solution of common salt, or oil, &c. With these and all fluids of a like nature convection proceeds more slowly, and the more viscid its nature the slower the liquid moves, until we have it in a solid or semi-solid state, when the particles will not circulate at all.

The most successful method of obtaining a greater heat is by sealing the apparatus, either wholly or by a weighted valve, so that a pressure greater than that of the atmosphere can be exerted on the water within it. This admits of the water reaching a higher temperature than 212° Fahr., and a less amount of radiating surface will do a given amount of work. There are objections, however, one being that the radiators become more unpleasantly, if not dangerously, hot, if accidentally touched or fallen against ; another, that such an apparatus (not having a "free blow off," as the Act puts it) comes under a much more troublesome section of the Building Act. This means of getting higher temperatures will be dealt with fully later.

Convection being caused by gravity, it follows that the more a material (i.e. its particles) expands by heat, the faster the convection currents must be, and it is on this account that the circulation of atmospheric air or any such light gas proceeds with great rapidity. A familiar experience of this is in gales, which, as well as gentle breezes, are all convection currents ; that is, a flow of cold air conveying itself to some spot where a rise of heated air is taking place. Trade winds and ocean currents all proceed in the same way, except that the former are convective currents of air and the other of water.

Thus far we have considered the question of convection as applied to the water in the boiler and the pipes, this water receiving the heat from the fire, which is conveyed through the boiler plate by conduction to the particles of water that are in contact with it, these particles starting off immediately, and conveying the heat to the desired locality. Now has to be explained how the heat is transferred from the pipes or coils to the surroundings, the heating of which has been the sole object of the apparatus.

It will be readily understood that it is not sufficient to merely bring the heated water into the pipes, but this heat must pass through the substance of the pipe, as it readily does by conduction (already explained), and it must then freely transmit itself to the surroundings. Now it has already been shown that by radiation heat is transferred from a heated surface in direct lines in all directions, its intensity being governed by the good or poor radiating powers of the surface coating. With hot-water pipes, in addition to this, we have another mode of heat transmission from the surface, viz. by convection, that is, the heating of air particles in contact with the pipe and the consequent circulation of air. It is the same action that occurs with water, excepting that with air the action is very much quicker with equally rapid distribution of the heat.

The action of convection takes place quite independently of the heat emitted by radiation, and it is the argument for and against open fires and hot-water pipes by grate-makers and hot-water engineers respectively. The grate-maker's contention is that open fires give the only natural result (that is, a result exactly similar to that given by the sun), by reason of their imparting heat to the body and surrounding things, rendering everything agreeable to the touch and to our feelings and senses generally ; and this without materially (we may say perceptibly) increasing the temperature of the air, and certainly without altering its general character. Whereas with any method of heating by hot water the cheerful brightness is lost, radiant heat (the congenial heat) is obtained in a less degree, and we have warmed air conveyed to our lungs which is not supposed to impart such a feeling of vitality as a cooler atmosphere. Also that in increasing the temperature, the saturation of the air, i.e. its volume of watery vapour, is not increased proportionately at the same time as would be the case in nature, so that a sense of dryness may be supposed to exist.

This is apparently a strong case for the grate-maker, but the hot-water engineer has a stronger one. In the first place a room warmed by a grate fire only, does not become comfortable until the radiant rays have imparted warmth to the contents of the room, the walls and floor. Most modern grates owe their greater efficacy to the heat projected on to the floor, and by this means imparting heat to the cold currents of air that exist there. When the contents and surfaces of the room have become warmed they cause the air to rise in temperature, and it is not till then that a sense of comfort is experienced. To occupy a room having the air quite cold would not be pleasant nor healthful, however bright the fire might be. It would be like sitting outdoors in the sunshine on a cold day.

It can be plainly seen that although the lungs may best like cold or cool air, the body objects, unless well clothed and in exercise. And this goes far to show that the lungs after all may only give the best results with cold air because, in so many instances, an air that is warm is not so fresh or pure. With a system of hot-water heating, properly erected, the air is only warmed to the extent that it soon becomes in rooms heated by grates. And there is the advantage that all draughts and currents of air in the house may have warmth imparted to them so that they lose their ill and disagreeable features. To complete the hot-water engineer's arguments it has to be added that the temperature of the rooms does not fluctuate. There is less attention, labour and untidiness. The sleeping rooms need not be so bitterly cold in the early morning hours (which all medical authorities consider hurtful to the aged and very young, and trying to all). The halls, staircases and landings are of a temperature equal to the rooms, so that doors can be dispensed with and curtains substituted, if desired. There is a very pronounced economy in fuel for equal results. The cheerfulness of the open fire is forgotten the same as it is when the weather is warm. The humidity of the atmosphere is not impaired by the heat given to it by low-pressure hot-water pipes; and there need be no less ventilation and no extra expense in attaining it than when open fire-grates are used.

For horticultural purposes hot-water pipes are eminently suited beyond all other methods of heating, by the regularity of the temperature obtained and the simple method of application. The heat can be so easily regulated as the weather or outer temperature varies, and it affords a simple means of increasing the humidity of the air for any description of plant life that needs it. By regulating the heat and moistness of the air in his glass-houses a gardener gets the results of different seasons of the year whenever he likes.

The convective action of air does not proceed wholly from the pipe surfaces, for we have it from every other object that is warm, whether these other objects have received their heat by radiation or otherwise, so that even with open grates we have warmed air to a considerable extent from its contact with our warm bodies, walls, furniture and general surroundings. Air may be said to receive heat by contact only, and this is what it is continually doing, robbing everything of heat that it comes in contact with (unless it be of a less temperature than itself, when it gets robbed in its turn). This, it may be mentioned, is an argument used and worn threadbare by some hot-water engineers as against the open grate, viz. that radiant heat warms one side of our bodies whilst the cool air is abstracting heat from the other side, whereas with hot water the air is directly warmed to a temperature beyond actual coldness. This argument is not strictly correct, for although we get a greater heat one side than another it is only while we directly intercept the hottest rays. If we move out of range of these rays we find a fairly equable heat in all other parts of the apartment.

It simply remains to be said that as heated air takes an upward direction the instant it is rarefied, all hot-water pipes and such heating media require to be near the floor, as at the ceiling it would indeed be a very long time before their good effects were noticeable below.

CHAPTER II.

CIRCULATION OF WATER, ETC.

UPON THE CIRCULATION OF WATER—Theory and phenomena—Tredgold's explanation and Hood's criticism and theory—Actual cause of circulation—Variation in results—Motive power—Table for determining motive power. CONNECTING PIPES TO BOILERS—Direction of pipes—Multiple flow and return services—Disadvantages of horizontal pipes—Various simple forms of apparatus and their leading features demonstrated—The most practical method.

THIS subject claims the attention of all who are in the least degree interested in hot-water works, as a knowledge in this direction is of primary importance in their design, except, perhaps, in cases where the apparatus requires to be of the most ordinary and commonplace description. In such instances the work is most usually left to workmen who, having erected many such before, are able to copy their previous undertakings without troubling to consider the reasons for the success they may probably bring about. When, however, the requirements are out of the common and some special form of apparatus, or some unusual feature is to be carried out, failure must, almost as a matter of course, ensue, unless the designer is properly and well acquainted with the different rules that govern the work, and particularly the phenomena of circulation.

Hood goes to some length to explain and make this subject clearly understood by the reader, and much profit can be gained from his description. He first points out that previous to his undertaking the task, Mr. Tredgold was the only person who attempted to describe the cause of the circulation of water, which he did as follows: "If the vessels A, B (Fig. 5) and the pipes connecting them be filled with water and the heat be applied to the vessel A, the effect of heat will expand the water in the vessel A, and the surface will in consequence rise to a higher level *a d*, the former general level surface being *b b*. The density of the fluid in the vessel A will also decrease in consequence of its expansion, but as soon as the column *c d* (above the level of the centre of the upper pipe) is of greater weight than the column *f e*, motion will commence along the upper pipe from A to B, and the change this motion produces in the equilibrium of the fluid will cause a corresponding motion in the lower pipe from B to A."

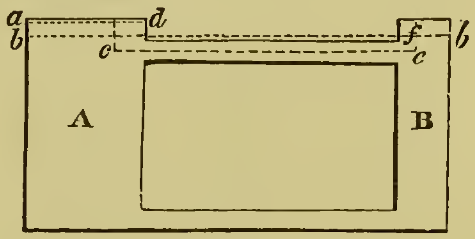

Fig. 5.

This explanation is far from being clear to the average mind at first reading, but to put other words to what it is intended to convey (with the hopes of making it more easily understood, if possible) it has to be explained that in this argument it is supposed that from the point *c*, which represents the centre of the upper pipe, to the point *b*, which represents the normal *cold*-water level (these two points are represented in exactly the same position at *e* and *b* or *e* and *f*), there exists a certain height of water, say 2 inches. When the water is heated in A, the expansion which takes place increases this height of water by, say, another inch (to *a d*). This 3 inches is then sufficient to outbalance the 2 inches at the top of vessel B (viz. from *e* to *f*), and consequently forces itself along the upper pipe in that direction, making a proportion of water travel along the lower pipe from B to A.

This, perhaps, is a lengthy explanation devoted to what Hood very correctly points out to be an erroneous theory which will not account for the circulatory action in every case, and he quickly explodes the matter by a description he gives of an apparatus similar to Mr. Tredgold's illustration, *but which will not admit of the water rising above the normal cold-water level* when heat is applied, and which would not work at all if the circulation depended upon the action described

The apparatus in question is as Fig. 6, which it will be instantly seen bears the closest resemblance to the other with the addition of an overflow pipe and two stop-taps. The description, which is in every way clear and worthy of repetition, is as follows—" Suppose the apparatus (Fig. 6) to be filled with cold water, and the two stopcocks to be closed. On applying heat to the vessel A, the water it contains will expand in bulk, and a part of it will flow through the waste-pipe x, *which is so placed as to prevent the water rising higher in the vessel* A *than the top of the vessel* B. The water which remains in the vessel A, after it has been heated and a portion of it has passed through the waste pipe x, will evidently be lighter than it was before, while its height will remain unaltered. Suppose now, the two cocks $f\,g$ to be simultaneously opened, the hot water in the boiler A will immediately flow towards B through the upper pipe, and the cold water in B will flow into A through the lower pipe, although by the hypothesis previously alluded to, unless the water in the vessel A above the pipe centre C were heavier or rose to a higher level than the water in the vessel B, no circulation could take place, and in this case another explanation must be found. The power which I consider explains this action is, let us suppose heat to be applied to the boiler A, Fig. 5, a dilatation of the volume of the water takes place and it becomes lighter; the heated particles rising upwards through the colder ones, which latter sink to the bottom by their greater specific gravity, and they in their turn become heated and expanded like the others.* As soon as the water in the boiler begins to acquire heat and to become lighter than that which is in the opposite vessel B, the water in the lower horizontal pipe d is pressed by a greater weight at z than at y, and it therefore moves towards A with a velocity and force equal to the difference in pressure at the two points y and z. The

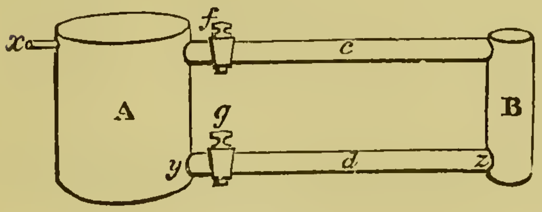

Fig. 6.

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* See Convection, Chapter I.

water in the upper part of the vessel B would now assume a lower level were it not that the pipe *c* furnishes a fresh supply from the boiler to replenish the deficiency. By this unequal pressure on the *lower* pipe, the water is forced to circulate through the apparatus, and it continues to do so as long as the water in B is colder, and therefore heavier than that in the boiler A."

The writer has made this rather extensive extract from the last edition, chiefly by reason of the argument being so soundly dealt with, and were it put in other words the ultimate amount of information imparted would have been about the same. It is so very necessary to impress upon the student that it is the superior weight of the colder water, *and this alone*, that brings about the movement of the particles, and ultimately the mass, of the liquid. It seems so natural to hear it argued that it is the fact of the hot water being lighter than the cold that brings about the circulation, whereas it is just the reverse. A distinction without a difference, some may say, but it is far from being so, as every practical man knows how many errors are fallen into through considering the ascending properties of hot water instead of the superior *descending force* of cold water, when working out some problem.

If we take a vessel of heated water (at any temperature) that is not being subjected to further heat nor cold, we shall find that it exhibits exactly the characteristics of cold water. So far as movement is concerned the particles will remain at rest if the vessel is not shaken, and it will be seen that the water has no tendency to rise, not any particle of it, yet from the very generally accepted notion that hot water has the power of rising, we might almost expect that the vessel would have to be sealed at the top to prevent it escaping.

If the vessel of hot water just referred to has some cold body placed at the top, a piece of cold metal or ice for instance, so that the upper stratum of water is cooled, a circulation will instantly set in (similar to that which would ensue if heat were applied at the bottom). In this case we cause cold particles to be above the heated particles, and this being contrary to the laws of gravity, the former by their superior weight displace the latter and find their way to the bottom, leaving a fresh supply of warm particles to come in contact with the cold object, to be cooled and sink in their turn and so on. This perhaps will give a clearer idea of how it is that the circulation of fluids is due to the superior weight of the cold particles, and *not* to the lightness of those which have been heated. It is simply the result we get when we place different substances in the pans of a pair of scales: the pan which contains the greater weight sinks, and that with the least weight rises, not because the lighter article has any inclination to rise, but because it is impelled by the superior force outbalancing it.

This difference in the weight of two columns or bodies of water, causing movement in opposite directions, has been designated the "motive power" of the circulation, a name which is of course strictly correct, yet does not at first give a very good conception of its meaning. Hood has set out a scale or table showing theoretically the speeds obtained in circulation by certain differences in temperature, which table will be quoted directly; but it is next to impossible to set up a standard for practical purposes, owing to the ever varying conditions that are met with. No two sets of pipes ever work under the same circumstances, and even one apparatus will not give exactly the same results always, as it may be influenced by changeable external conditions. It would be difficult to compile any reliable information in this direction, and after all there would be its difficulty of application. In the first place it would be necessary to complete the erection of the apparatus in every part, then charge it, and when this was done it could be very easily tested in the ordinary way to see if it fulfilled the designer's expectations, and gave the desired temperature. If it did this no further trouble would be needed, whereas if we tested the speed of the circulation and it proved satisfactory, it would by no means indicate the success of the work, as it would not tell us if there were sufficient pipe or radiating media, nor would it tell us if the pipes were well placed, in fact it might prove misleading.

In dwelling upon the non-practical utility of the table referred to, it is with no desire to underestimate its value in other ways, and apart from its scientific use it is desirable information to impart as showing exactly what constitutes motive power in hot-water circulation.

DIFFERENCE IN WEIGHT OF TWO COLUMNS OF WATER, EACH ONE FOOT HIGH, AT VARIOUS TEMPERATURES. (Hood)

Difference in Temperature of the two Columns of Water, in degrees of Fahrenheit's scale.	Difference in Weight of two Columns of Water contained in different sized Pipes, each ONE FOOT in height.				
	1 in. diam.	2 in. diam.	3 in. diam.	4 in. diam.	Per square inch.
°	grains.	grains.	grains.	grains.	grains.
2	1·5	6·3	14·3	25·4	2·028
4	3·1	12·7	28·8	51·1	4·068
6	4·7	19·1	43·3	76·7	6·108
8	6·4	25·6	57·9	102·5	8·160
10	8·0	32·0	72·3	128·1	10·200
12	9·6	38·5	87·0	154·1	12·264
14	11·2	45·0	101·7	180·0	14·328
16	12·8	51·4	116·3	205·9	16·392
18	14·4	57·9	131·0	231·9	18·456
20	16·1	64·5	145·7	258·0	20·532

The above table, on account of its accuracy, may well be considered a testimonial to the exceeding care exercised by Hood in compiling his data.

The above table has been calculated upon the difference in the temperatures of from 170° to 190°, these two temperatures being about the heat that is obtained in a well-constructed apparatus when in full work.

This table, it will be noticed, gives the difference in weight between water at two different temperatures *per foot* in height, so that in arriving at the actual motive power exerted in an apparatus, we must take the height from say the centre of the return pipe, where it enters the boiler, to the top of the flow pipe, where it ceases to travel vertically, as at *a*, Fig. 7. This distance varies from a few inches to three or four feet in common horticultural work; taking an apparatus of an ordinary kind we will suppose this distance is three feet. We next have to ascertain the temperature of the water that enters the boiler from the return pipe, and that which leaves the boiler by the flow pipe, both temperatures to be taken at points as near to the boiler as possible. Supposing the pipe to be 4-inch, and the difference to be 16°, we get from the foregoing table 205 grains per foot, × 3 = 615 grains = 1¼ ounce, and this weight, which will strike the reader as being exceedingly trifling, constitutes the motive power of the circulation in an apparatus. This very small difference in the weights of the water is, however, under ordinary circumstances, capable of setting up a tolerably rapid movement, notwithstanding that in the average apparatus there may be as much as 210 gallons = 2100 pounds of water to be made to circulate. In water, fortunately, we have a material peculiarly adapted to this purpose, as owing to its perfect mobility, friction does not play a very important part in its passage through the pipes; if it did, failure would be inevitable.

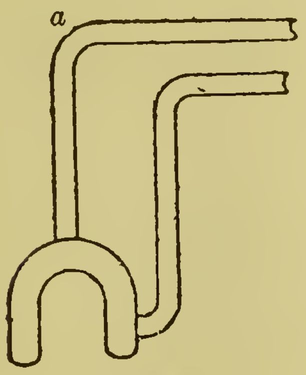

Fig. 7.

From the results just explained we gather two points of importance: first, that by increasing the difference in temperature between the water entering the boiler by the return pipe and that leaving the boiler by the flow pipe, we shall obtain an increase of motive power (i. e. the speed of circulation); and, secondly, that the more we can carry the flow and return pipes in a *vertical* direction, the faster will the water circulate, with proportionately better results. When an apparatus is first started (by applying heat to the boiler), the results are quickened by the fact that a *considerable* difference in temperature exists between the water entering and that leaving the boiler just at this time, as all the water passing in from the return pipe is *quite cold;* but after the whole is heated up a less difference exists, but the water continues to circulate at almost the same speed. It does not always follow that the more the fire is urged the greater the speed of circulation, as although the water will leave the boiler at a higher temperature (and diffuse a greater heat), yet it will return into the boiler at a higher temperature also, so that the difference in gravity between the two columns remains almost the same.

It is quite surprising to note what an exceedingly low degree of heat will bring about movement amongst the particles of water. In the glass models of apparatus already referred to, it will be noticed that particles of water commence to rise almost *instantly* the heat is applied, hardly allowing time for the heat to pass through the substance of the vessel, and when once the circulation is established, many particles will be noticed flying upwards at a velocity that could scarcely be followed with the eye if the water was not confined to a small space. This bears out the theory that not only is there an absolute want of cohesion amongst the molecules, but there must be a repelling influence exerted, otherwise how could such an extraordinary absence of friction be manifested?

In considering the small amount or value of the power that produces a circulation in such a large bulk of water, it naturally brings to mind, as Hood points out, that a trifling obstruction or error in workmanship must have a very prejudicial effect, or probably ruin the efficiency of the work. But it is rather unusual to hear of such failures: that is, they are very small in number compared to the successes, notwithstanding that there are about as many such undertakings working with a low motive power (nearly all horticultural works) as with high. With careful workmanship and attention to the rules laid down, success nearly always ensues as a matter of course.

CONNECTING PIPES TO BOILERS.*

One of the most necessary rules to be observed in hot-water works is, as to the point at which the flow pipe is connected into the boiler. From what we have learnt of the action of convection the flow pipe should be connected up at the top of the boiler in readiness to convey away the heated particles of water in the direction required. But merely connecting this pipe at a high point is not sufficient, it must be connected at *the very highest point,* as at Fig. 8 for instance.

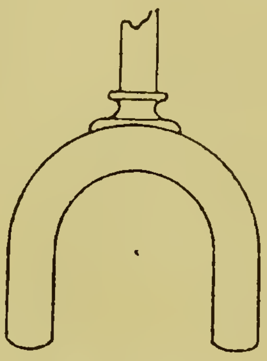

Fig. 8.

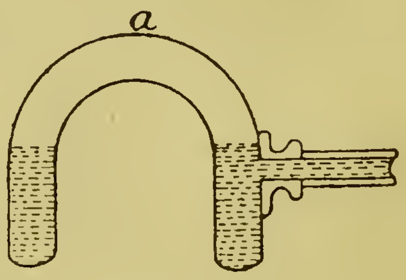

Fig. 9.

The reason for this is that, supposing the flow pipe to be connected at some lower point, as at Fig. 9, we should be unable to expel all the air from the boiler. In other words, we could not fill the boiler with water above the top of the flow pipe, as shown, for unless the air be expelled, we cannot get water to enter. Air and water cannot occupy the same space at the same time, and this accumulation of air will prove a great obstacle to the free circulation. Now, if we placed an air cock at the point marked *a*, we could quickly dispose of the air for the time being, and get the boiler quite full of water. But it would only give temporary relief, as water, particularly in cooling, readily absorbs air, and when heated parts with it again, and the air may always be looked for at the highest points; consequently this air cock would require fairly constant attention. If, on the other hand, we put an air *pipe* at the point *a*, the difficulty experienced by air collection would be overcome (this pipe having an open end above the level of the supply cistern), except that it is against all recognised principles to start the flow pipe horizontally from the side of a boiler if the work is of any magnitude; though for small works it is permissible.

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* These particulars will be found to apply chiefly to horticultural works, but the principle involved is the same with all boilers, and applicable generally.

After starting the flow pipe from the extreme top of the boiler,* it should be continued in a vertical direction as far as it is possible, so as to favour the motive power to the greatest extent, although in many horticultural works there is oftentimes only room for a few inches of vertical pipe, a bend having frequently to be placed directly on the boiler, as Fig. 10.

All the vertical pipe in an apparatus goes to increase the motive power and the consequent quicker results; that is to say, if the pipe rises one foot from the boiler before it is carried horizontally, and then it rises another foot and then another, we can calculate upon having three feet of vertical pipe, although it is not all immediately near the boiler. All vertical pipe aids in increasing the circulation; horizontal pipe does not aid in the least wherever it is situated; in fact, it is the reverse, owing to the friction it involves, and all matter, sediment, &c., collects in these pipes.

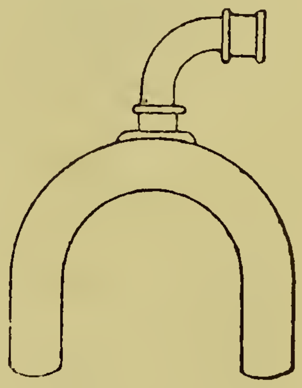

Fig. 10.

In many instances it is found desirable to have two or more flow pipes. This can be done with every satisfaction, and the writer is rather in favour of this arrangement, where it is convenient and the circumstances make it desirable, in preference to the one flow pipe and its many branch services.

The position in which the return pipe enters the boiler is not so important as the flow pipe, but at the same time it should not be brought in anywhere. The usual and correct place to bring it in is close to the bottom of the boiler, and it is very desirable to arrange that while the flow pipe is towards one end of the boiler, the return pipe enters at the other, if the boiler is of a horizontal shape. As a rule the flow pipe is kept to the front and the return to the back, as Fig. 11, and a circulation is thus ensured right through the boiler. The boiler should be tilted up slightly at that end where the flow pipe is connected. An apparatus of fair size has usually two returns (although perhaps but one flow), and this practice is to be highly commended as equalising the action in the boiler. It also reduces the likelihood of fracture of the boiler plate.*

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* If it is a wrought-iron pipe screwed into the substance of the boiler, the pipe must on no account be screwed right through so as to project inside, otherwise the objectionable accumulation of air must ensue. It is proper to have a flange on the boiler to receive the pipe.

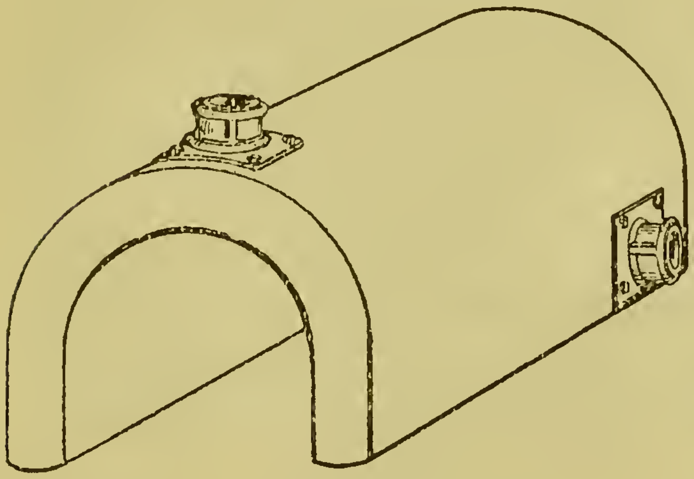
Fig. 11.

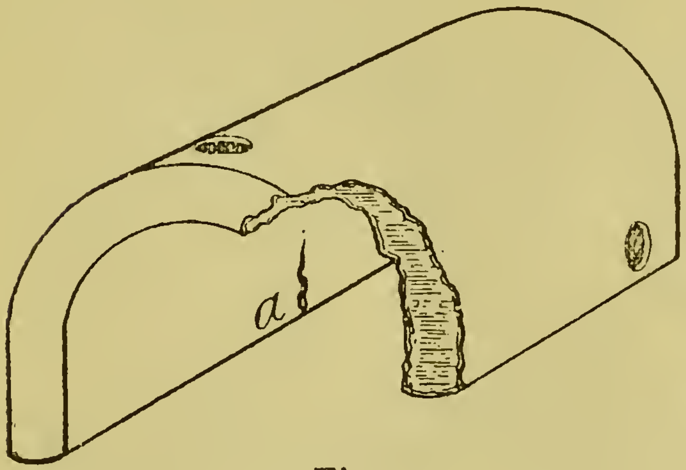

Fig. 12.

The flow pipe, which, as already explained, starts from the top of the boiler, is taken vertically as far as possible, and then† it is usually continued at right angles, i.e. horizontally; but every practical man arranges to give the horizontal pipe a rise where at all possible, if only an inch or two in fifty feet. There is then a natural inclination for the water in the return pipe to aid in the motive power; and though the inclination be trifling, it is better than a perfectly horizontal pipe in which we may suppose the water remains quite inactive unless propelled by another force. This gradual rise, as Fig. 13, is continued to the farthest limit of the apparatus.

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* It is found that with very many boilers that are taken out fractured, and which have only one return pipe, the fracture has occurred on the side opposite to that where the return is connected, as shown at Fig. 12, the fracture being due to an accumulation of sedimentary deposit at this point which has kept the water from having free contact with the metal, thus ending in the destruction of the fibre by the heat. This deposit could not have occurred just there had there been a return pipe at that side. The fracture shown is exaggerated as to size, and marked *a*.

† We shall deal with horticultural work first, and speak of other systems, in which a great deal more vertical pipe is obtainable, presently; but the same general principles apply to both.

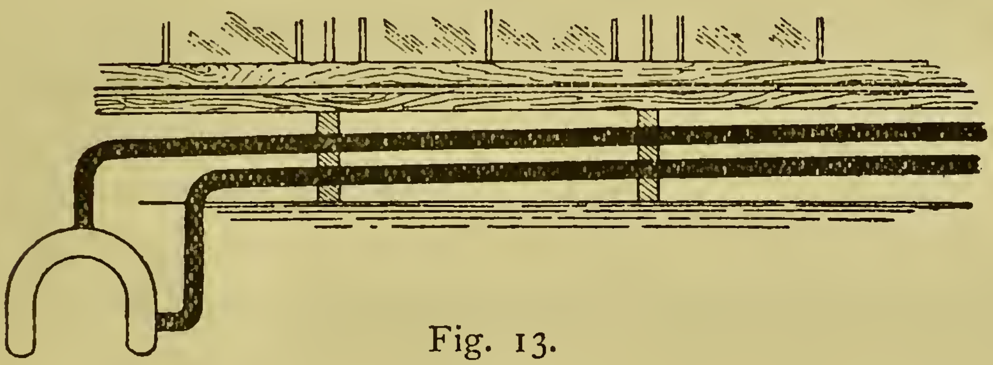

Fig. 13.

It may be mentioned that it is quite possible to get this rise if care be exercised in planning the work, and as every glass-house for horticultural purposes has, as a matter of course, to be heated, the builder (who may also do the hot-water work) arranges the structure to the best advantage, putting the boiler pit at the lowest point. And where there are a series of houses it is very advantageous if they can be put on slightly rising ground so that each house is some inches higher than the preceding one.

There is an idea rather prevalent, especially amongst workmen, that it is necessary always to keep the flow pipe above or over the return, as shown at Fig. 13. This is not really necessary, although preferable, but it is not always convenient and sometimes hardly possible, and when pipes are carried in shallow trenches or laid beneath gratings it is usually necessary to run them side by side. If, however, it is required to carry them along the side of a wall, then they are placed one above the other. In any case if the flow pipe rises to a certain height above the boiler the motive power will be the same whether it be carried above the return or whether they be carried side by side ; or in other words, either arrangement will prove equally satisfactory under similar general conditions.

There can occasionally (though rarely) be met with an apparatus in which the return pipe is brought back over the flow, as at Fig. 14. This, according to general supposition, is opposed to good principles, and the general verdict would be that the apparatus was the result of employing insufficiently skilled labour, as possibly might be the case, but whatever comments might be passed, the apparatus (if all its other features were correct) would be found to work satisfactorily.

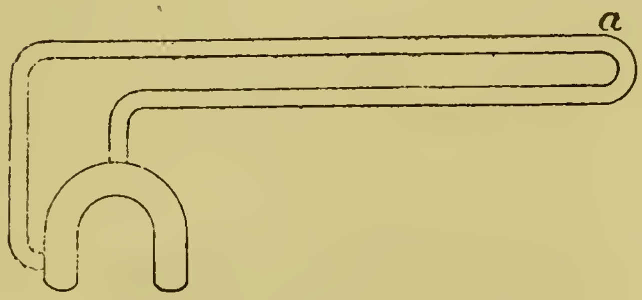

Fig. 14.

In this apparatus as illustrated, the flow pipe will act as a flow pipe* up to the point marked *a* (supposing the pipes have a gradual rise to this point, as should always be the case, as explained), and from this point the water will commence to fall or return, and by its gravity produce the needed circulation. In this case we get exactly the same length of horizontal and vertical pipe in the return as if the apparatus were constructed as at Fig. 15 (which is a copy of Fig. 14 with the position of the pipes altered) ; consequently exactly the same results are obtained

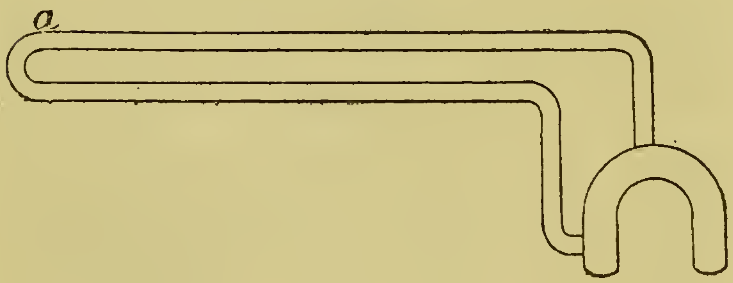

Fig. 15.

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* It sometimes seems difficult to fix the point in an apparatus where the flow pipe terminates and the return pipe begins, especially as one is merely a simple continuation of the other ; but it is usual to consider the flow pipe as extending from the top of the boiler to the highest point in the apparatus, and from this highest point the continuation of the pipe is considered to be the return, even in a form such as Fig. 21.

practically. In theory we might expect results of a little better nature owing to the whole of the vertical portion of the return pipe being near the boiler, as will be explained directly.

It is not by any means intended to recommend this arrangement of the pipes in preference to the customary method, for in the first place the difference in actual results would not be appreciable, nor could it be detected at all except in a very large undertaking, and then only to a trifling extent. To advocate such a change for practically no benefit whatever would be useless, and would lead to endless trouble and confusion amongst workmen. This unusual arrangement is merely described to show that were it necessary it might be carried out without hesitation; even a branch service from an ordinary apparatus could be so carried if particularly convenient.

In support of our view of the importance of having the whole of the *vertical* portion of the *return* pipe as near to the boiler as can be arranged, we cannot do better than quote Hood's words, on account of the very lucid manner in which he deals with this much disputed question.* He says: "As the water in the pipes is constantly parting with its heat both by radiation and conduction, while that in the boiler is as continually receiving additional heat from the fire, an equality of temperature never can occur; consequently, as the circulation is caused by the water in the descending pipe being colder, and therefore heavier, than that which is in the boiler, it follows, as a necessary consequence, that the colder the water in the descending pipe shall be relatively to that in the boiler, so much the more rapid will be its motion in the pipes. In an arrangement of pipes as Fig. 16 the water in the descending pipe *c d* having to come a greater distance before it descends to the lower part of the boiler than when the pipes are arranged as Fig. 17, it will of course be colder at the time of its descent in Fig. 16 than Fig. 17, and therefore the circulation will be more rapid." *

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* This question is very much debated even at this present time, and even by those who profess to be authorities upon the subject, but who, it must be inferred, lack some of the more preliminary knowledge necessary in discussing the matter. The theory established by Hood is strictly correct in actual practice, and can be relied upon.

It will be seen very clearly that the water in the descending pipe (which is furthest from the boiler) in Fig. 17 must necessarily have hotter water in it than when the water has to travel a still greater distance before it descends, as Fig. 16, and has therefore lost more of its heat. This can be shown still more clearly by spacing off the pipe and supposing that the water, by radiation, &c., loses five degrees of heat in traversing each length of space so marked. In Fig. 18 we will suppose the water starts from the boiler at 200° and

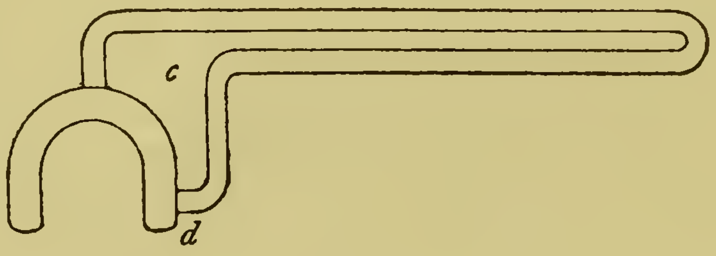

Fig. 16.

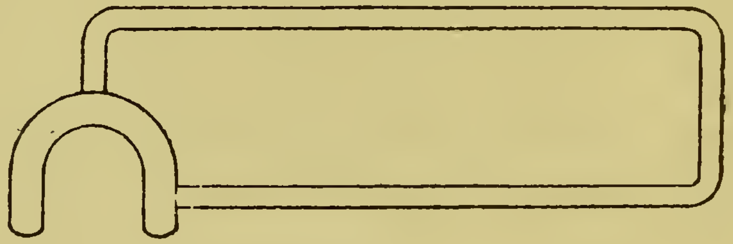

Fig. 17.

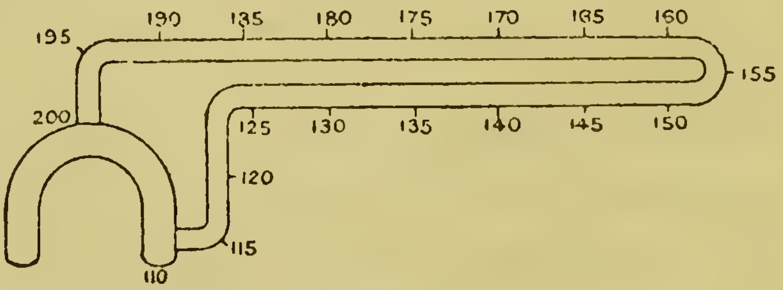

Fig. 18.

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* As Hood remarks, it is very necessary, when studying this work, to avoid the erroneous hypothesis that the motion of the water commences in the upper pipe instead of the lower one.

returns into it at 110°,* the water losing five degrees of heat each space it passes through. And let us also suppose that for each five degrees of temperature lost there is an increase

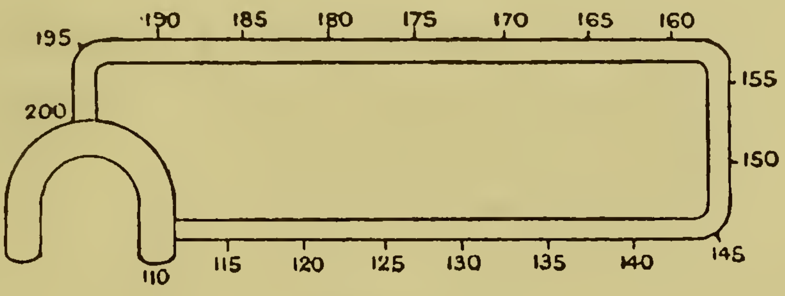

Fig. 19.

of weight of 20 grains; we can then see almost at a glance that in Fig. 18 the water when it reaches the descending pipe will be 300 grains heavier (for a given bulk) than when it

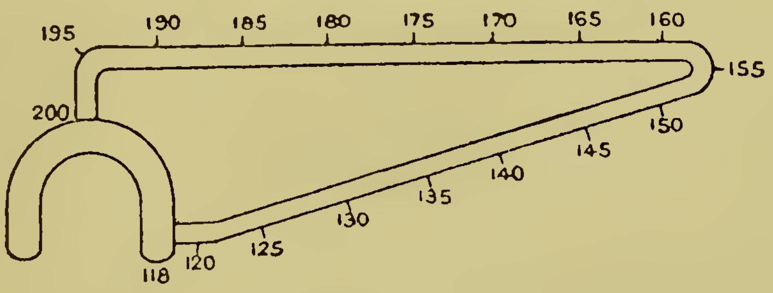

Fig. 20.

issued from the boiler, whereas in Fig. 19 it will be but 170 grains heavier and so proportionately less in motive power.

Figs. 20 and 21 show two methods of which there will

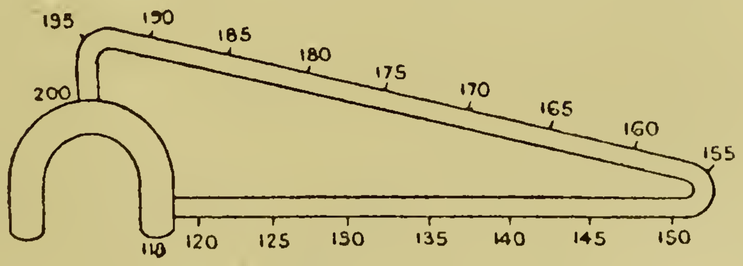

Fig. 21.

occasionally be found advocates, who contend that better results are obtainable by these arrangements than if the work is carried out in the ordinary way.

It should be first mentioned that only in a simple form of apparatus could either of these methods be adopted, as any system of branch or secondary services would be almost impossible unless the circumstances happened to be very favourable. With Fig. 20 the contention is that instead of carrying any portion of the return pipe horizontally, which is of no assistance to the motive power, the return should be made to slope down all the way, commencing at the termination of the flow pipe, and ending at the boiler, as shown ; so that the water commences to exert its downward force from beginning to end of this pipe, no portion of the pipe being valueless as regards assisting in the motion of the water. This, it must be admitted, makes up a very fair case for the advocates of the method, but upon analysis it is very weak, and the method recommended (Fig. 18) will give the best results practically as well as theoretically.

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* These are, of course, supposed temperatures.

If we space this apparatus off as we did the last, we shall find that in the return pipe we have an average temperature of 135°, which, according to the method adopted, represents water having a gravity superior to that just leaving the boiler by 260 grains. And, although the return pipe of this apparatus slopes a long way, the actual fall it has is no more than in Fig. 18. To get comparative results in each case we must take the average temperature of the water in the return pipe of each system (not allowing horizontal pipe to enter into the calculation in either instance), and that which shows the least temperature has the greatest motive power, as in each case the water is shown leaving the boiler att he same heat, viz. 200°.

In the apparatus now being described there is an average temperature of 135° in the sloping return pipe, representing an increase in weight of 260 grains, as already stated. On taking the average of Fig. 18 (the style of apparatus most recommended), we get an average temperature of 120° in the *active* part of the return pipe, and this represents an increased weight of 320 grains, which conclusively proves that it is a

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[*] It is desirable to again remind the reader that these temperatures and weights are purely supposititious, although not such a great way from those actually found.

more efficacious arrangement than that with the sloping return as in Fig. 20.

This plan of sloping the return pipe in the manner shown would give better results than erecting the apparatus as at Fig. 19; in fact it would be equal to putting the descending portion of the return pipe half-way between the boiler and the termination of the flow pipe, as Fig. 22.

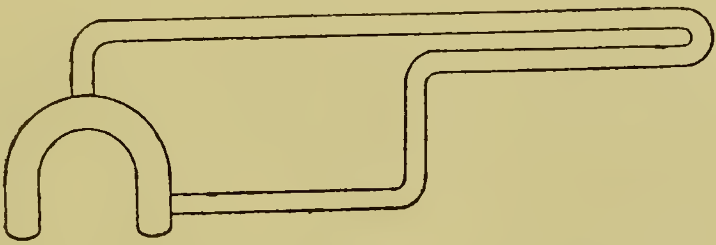

Fig. 22.

Apart from the question of effectiveness, this method has hardly ever been adopted, owing to the trouble that must necessarily ensue when an apparatus is not confined to a few straight lines of pipes.

In Fig. 21, which Hood illustrates and very clearly explains, we should get worse results than with any method yet explained; yet, strange to say, there are a good many people who, if not quite positive, are quite ready to give an opinion in favour of having the flow pipe commencing to descend immediately after it leaves the boiler, the contention being that, by making the pipes almost wholly return services, the motive power will be aided proportionately. This argument, however, is not sound, for in the first place, although the flow pipe is not continued to the further end of the apparatus, yet what we may call the active part, i. e. the ascending column of the flow pipe, is not disposed of. As explained with the last method, the sloping return, although perhaps extending a long way, has only an actual fall of two or three feet, and this fall takes place where the water is of least weight, and by the method used in calculating the results obtained in the other systems, we shall find that the effect obtained is the same as constructing an apparatus as Fig. 23. There is but one way of making the system less effective (without wholly destroying its efficiency), and that would be to make the apparatus as this last illustration, but with the descending pipe still closer to the boiler.

Any one of the methods explained will work—that is to say, the water will circulate within them, and in a small apparatus, such as we should erect in a greenhouse, it is doubtful if any difference in results would be perceptible. But in an undertaking of even a moderate character, much trouble might arise with the less efficient methods, as not only does the apparatus require to be working at its best, with the least expenditure of fuel and labour, but with a good quantity of pipe and its ramifications a greater resistance is opposed to the motive power, which, if not strong, might be actually nullified. We have seen that in horticultural works, which are very dwarfed as to height, the circulation is the result of but a few ounces difference in weight of the entering and outflowing water at the boiler, under favourable circumstances. The principle described under Fig. 18 is considered and been found the best, both by theorists and practical workers.

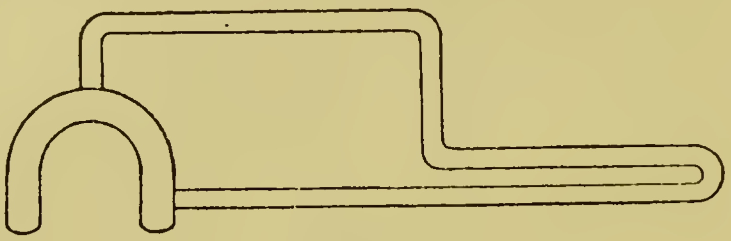

Fig. 23.

CHAPTER III.*

AIR IN PIPES—SUPPLY OF WATER—EXPANSION OF PIPES.

AIR IN PIPES—Accumulation and dislodgment—Air pipes and cocks—Stoppage of air vents. WATER SUPPLY—Provision to replenish loss by evaporation, also when water is drawn off—Expansion of water by heat—Capacity of supply cisterns—Overflow—Position of cistern—Service pipe and connections—Rain or hard water—Sediment or lime deposit—Useful appliance for small purposes—Flushing and cleansing. EXPANSION OF PIPES—Provision for expansion—Measure of expansion—Pipe bearings.

THE preceding chapter has only dealt with the most elementary details; yet before proceeding further it is necessary to speak of a subject which plays an important part in the execution of these works, and which should be explained before going further. This is the dislodgment of air from the pipes, a collection of air at some unexpected point being one of the most prolific and annoying sources of trouble and vexation possible, owing to its so effectively impairing the circulation. And we must also deal with the means adopted to supply the apparatus with water, to make good the loss by evaporation, or any that may be drawn away.

When an apparatus is newly constructed, the boiler, pipes, and all appurtenances are, of course, filled with air previous to their being charged with water. When the water is admitted, the air is driven to the highest point, where it will persistently stay, whether the pressure of water be high or low, and most effectually prevent the water circulating. We cannot by any means make the air quit its high position and descend, and so escape by the supply pipe. Not even if we could get the water to circulate can we get it to carry any accumulation of air, however small, *downwards.* Consequently a means has to be provided in the shape of a cock or small open pipe to allow of the free escape of collected air, not only when first charging, but afterwards, as the water when fluctuating in temperature is continually absorbing and expelling air.

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* The information given in this chapter will be found to apply chiefly to horticultural works, but the principles involved apply to all systems of apparatus.

In a simple apparatus, as Fig. 24, the water in the two pipes would be effectually prevented from having contact, as shown, if no air outlet was provided, but with a pipe or cock at *a,* the trouble is instantly overcome.

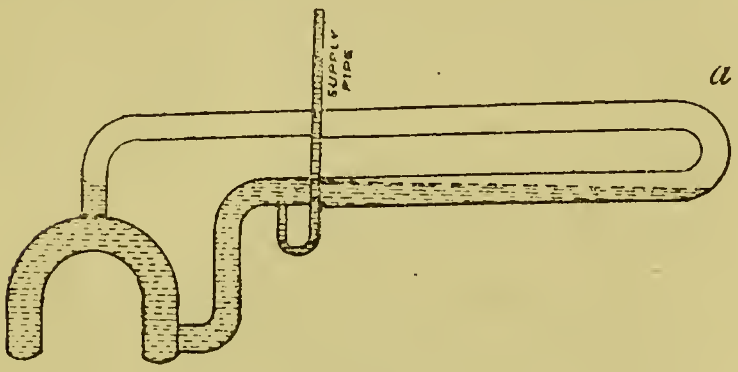


Fig. 24.

Of course it is easy to suppose that fixing the points for the air vents is a simple task, owing to the air finding the highest position due to its being so many times lighter than water. But this is not exactly the case, for in the ramification of an extensive system it is not at all an unusual thing for some point to be overlooked, and so cause trouble until remedied, and the remedy sometimes partakes of the nature of a problem. If a flow pipe of any length is run quite level (which fortunately is rarely necessary, as a rise, however little, can usually be got), the air will collect in great bubbles at irregular points along its whole length, whether this pipe be the highest one, or whether it is only one of a series. In such a case it would be desirable to have two or three air vents along the pipe when first charging, as the air globules *do not move* when the water circulates (they would if the pipe had a rise), but remain in their positions most tenaciously, the water, when circulating, passing under, as Fig. 25. This can be ascertained very quickly in any glass model or experimental apparatus.

The most simple and effective air vent is an open pipe. This may be in iron, copper, or composition tube. In size it varies from $\frac{1}{4}$ inch to $\frac{3}{4}$ inch, but both these are extremes. As air can escape from an aperture with exceeding rapidity, it is not necessary to have a large tube, and accordingly $\frac{3}{8}$ inch and $\frac{1}{2}$ inch are the two sizes commonly used. If the latter, it is the iron gas tube that is most usually employed; but with the former, copper tube generally takes its place, as this can be readily bent, and the small quantity required makes but little difference in cost.

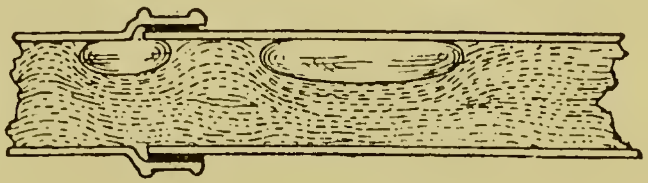
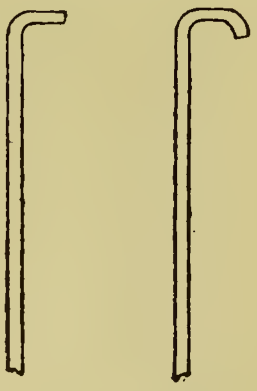


Fig. 25.

Composition tube (a soft metal tube commonly called "compo,") is inexpensive, and readily bent to any desired angle; but its softness is objectionable, as being so readily injured and disfigured by trifling mishaps, and as an air pipe is commonly a conspicuous object, its appearance is often considered.

Air tubes, especially when they have two or three bends in them, may sometimes become stopped by dust and débris, assisted by cobweb, and for this reason, although a $\frac{1}{8}$-inch pipe would give free vent to the air, it is not desirable to use it. To prevent a stoppage as much as possible, it is a good practice not to leave the pipe pointing upwards, but turned over either as Fig. 26 or Fig. 27; and to facilitate removal, if they require clearing, a union should be used to connect this tube with the hot-water pipe.



Figs. 26, 27.

One very important feature connected with these tubes is that they must not on any account dip downwards, that is to say, like the flow pipe of a hot-water apparatus, they must either be vertical, or ascending to some degree. A horizontal pipe is hardly permissible, and an air pipe that descends in the least degree is utterly wrong. If an air pipe is carried downwards at any point, as at Fig. 28 for example, this pipe may be quite clear, and fulfil the duties of an air vent properly when first the apparatus is charged. After the apparatus has been in use a short time, however, water will collect at *a*, by condensation of vapour (and in time a collection of dirt particles will also be found there), and this small quantity of water will effectually prevent the free exit of any air that may collect afterwards. It must be remembered that there is no pressure exerted to expel the air, unless the boiler be overfired and generate steam. It is practically the same effect as is obtained by putting a trap in a bath waste pipe, this trap holding a small quantity of water to prevent the passage of objectionable gases, which it does successfully—a success which has objectionable qualities in the air pipe of a hot-water apparatus.

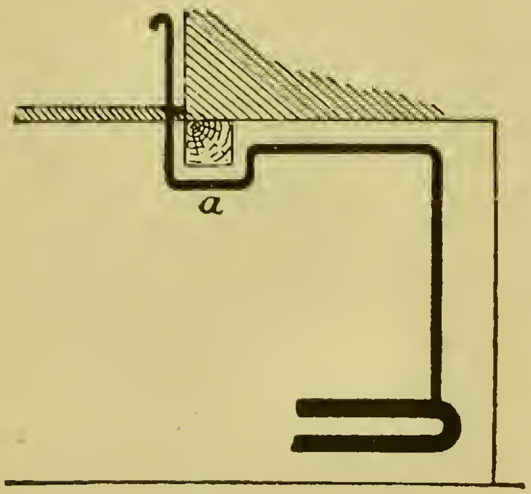


Fig. 28.

No portion of an air pipe which contains water must be carried outside, or it will be seriously affected by frost. An air pipe cannot conveniently be used with an apparatus that extends through several floors of a building, owing to the great length some of the pipes would have to be,* and resort has then to be made to a cock or automatic air vent.

An air cock is usually of a shape similar to Fig. 29 (full size), which has an internal construction very much like an ordinary tap, but the " way " or passage through it is only about $\frac{1}{8}$ or $\frac{3}{16}$ inch in diameter, which, however, is ample for the purpose, as these are things that cannot get stopped up in any way like an air pipe. The screw portion is commonly made to fit into a hole which is drilled and tapped for ¼-inch gas thread (pipe). A more improved form of cock is as Fig. 30 (full size).* This form is a decided improvement, being less subject to leakage from wear and use, and less

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* There has to be an air vent to every distinct service and to every coil, radiator, &c., so that in an extensive apparatus of this character twenty or thirty vents might be needed; but so many as this are rarely needed in the low-lying horticultural class of work.

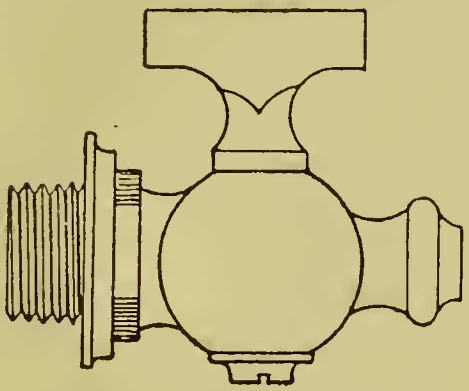

Fig. 29.

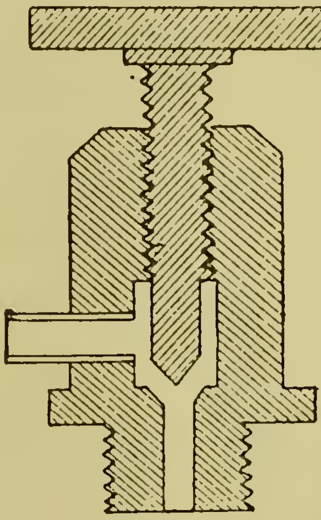

Fig. 30.

likely to stick tight. The makers claim that as the nozzle is situated at the side, there is less likelihood of damage being done when turned on, should it be in proximity to a wall or decorations.

When an air tap is opened (i.e. turned on), if there is any air in the pipe, it escapes; but we can never tell if the whole of the air has escaped until water issues, and if there is any pressure the water will be ejected to a considerable distance, oftentimes wetting the ceiling if an upright air cock is used as Fig. 29. The other form of cock, Fig. 30, is supposed to overcome this, as the outlet is at the side; but it must be submitted that if the ceiling escapes injury, the water may still be projected against a wall. With either form of cock this trouble can be overcome by holding a cloth, or some such substance, over the tap when discharging the air.

There are two forms of automatic air vents to be had; but although such appliances are much needed, the writer hesitates to recommend them, owing to the bare possibility of their failing at some time, early or late, which failure would be almost a calamity in some instances. Should it, for instance, be in a position situated over a valuable ceiling, the leakage would in a few moments do some harm. Or in a grape house the possible flood of water might ruin the vines, which at times need a dry atmosphere, besides causing an instant fall in the temperature, which, if occurring in the night, would work endless mischief in any horticultural building.

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* Also see air cocks for radiators.

SUPPLY CISTERNS, ETC.

It is, of course, necessary to provide some means, not only of filling a hot-water apparatus in the first place, but also of replenishing the waste of water that takes place from evaporation, and that which may be drawn off, if a means of drawing water off is provided. Between an apparatus that loses water by evaporation only and one that has water drawn from it as well,* some difference may exist in the provision for replenishing, and it will be best to speak of each separately, the former arrangement being taken first.

In this case a supply cistern has to be provided, this cistern being very commonly of cast iron, either plain or galvanised, and its size requires to be governed by the magnitude of the apparatus in the following way:—

Water expands, i.e. increases in bulk, upon the application of heat, the expansion uniformly increasing as the temperature rises, so that a vessel exactly filled with cold water would, when heated, overflow. Therefore, if a cistern of insufficient size were provided, it would not be capable of holding the increased quantity or margin that has to be provided for when the water is heated.

Water, when heated from freezing to boiling point, expands one twenty-fourth—that is to say, twenty-five gallons of boiling water equal in weight (and original capacity) twenty-four gallons of water at freezing point; or, in other words, water near freezing point occupying 24 inches space in a vessel, would, upon being heated to 212°, be found to be occupying 25 inches. But in hot-water works we need not make provision to quite this extent, as the two extremes of heat named are not experienced, and the calculation need only be based upon a difference of about 150°, that is, from 50° to 200°. This, according to the above result, would give us an increase in bulk of about 1 in 30; so that by using a cistern having this capacity between the cold-water line and the overflow, as Fig. 31, we shall get the room required.*

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* The writer is still alluding to horticultural work, in which a deal of warm or tepid water is required for watering melon and cucumber pits, and for many other purposes.

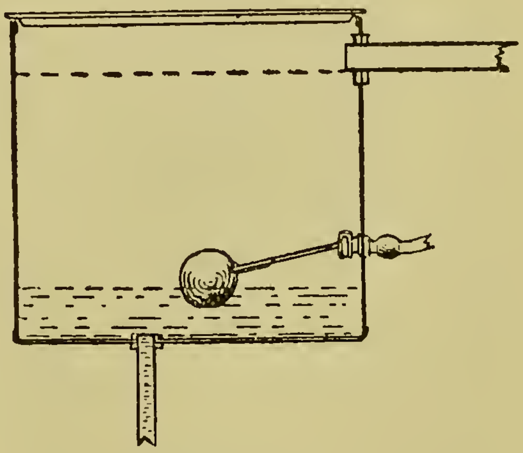

Fig. 31.

In building works, or instances where an overflow of water would be objectionable, it is very desirable that an overflow pipe be put to the supply cistern. In horticultural works, however, this care is not always exercised, as a little water spilled on the ground may do no harm. In any case the apparatus, when charged with cold water, is not charged so as to fill the cistern full. If filled so that only an inch or two is at the bottom of the cistern it will be correct, as the expansion of the water, when heated, will fill the cistern up. This is the objection to using a ball valve, as at first it is covered with water when the expansion occurs.

The quantity of water that is lost by evaporation only is very trifling, perhaps a quart per week (according to the size or heating properties of the apparatus), and if none is drawn off, a ball valve to automatically replenish the loss is not necessary, and is sometimes fruitful of mischief. These appliances are ever ready to refuse to act when they have little work, as they get stiff in the working parts. When water is drawn off for any purpose whatever, it is very desirable and necessary to have a ball valve or cock; but care should be exercised to get one of a good quality, as a really perfect article of this description has not been made yet.

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* See table at end giving capacities of pipes, &c. As an instance, 500 feet of 4-inch pipe and the boiler would contain about 280 gallons. This divided by 30 gives 9½ gallons, which represents the least capacity the cistern should have between the points named; unless the overflow pipe of the cistern is of good size and relied upon to take away the surplus water (see following pages).

The position in which the supply cistern should be fixed is governed to some extent by circumstances; it is usually placed as near the boiler as possible, but there may be no objection to its being at the further extremity if desirable. If there are several branches to an apparatus, any of which can be shut dead off, then it will not do to put the cold supply into one of these. It may, however, be connected at any point where stop valves or cocks in the circulation, if closed, will not interfere with the supply of water to the boiler. There is sometimes a doubt as to whether or not an advantage is gained by carrying the supply service into the boiler itself instead of into a pipe; but there is no strong argument in favour of this; in fact, there is a greater likelihood of the water in the cistern becoming hot by this means. The best arrangement by far, and which is adopted by all the leading specialists, is to connect the cold supply service into a return pipe, this service (cold supply) dipping down below the return pipe before entering it, as Fig. 32, or having what is called a "siphon," in reality a double bend, as Fig. 33, to prevent the hot water circulating up it, as it might do if the pipe proceeded straight from one point to the other.* Some prefer to adopt both measures, as Fig. 34.

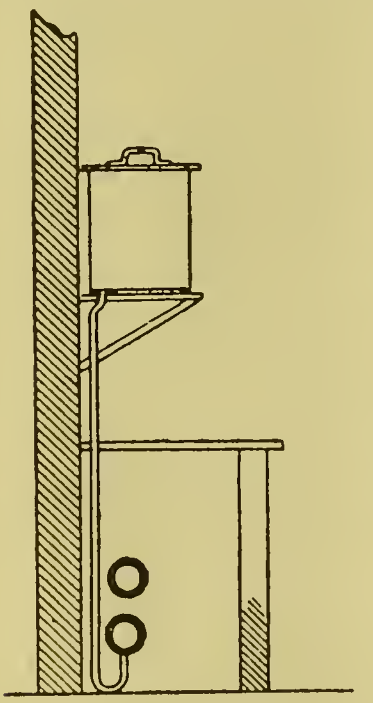

Fig. 32.

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* In this we have illustrated a phenomenon peculiar to the earliest form of hot-water apparatus in which but one pipe is used. In this arrangement the pipes could never be allowed to dip down to the slightest

There needs, however, to be pointed out a rather serious fault in the connections of Figs. 33 and 34, the double bend shown being a prolific source of trouble if it has no air vent to its upper part. It is not at first charging that any trouble will occur, but when re-charging after the apparatus has been emptied for some purpose. When the apparatus is emptied, the lower part of this bend will remain full of water, as Fig. 35. When re-charging the water will attempt to pass down this pipe, and some may succeed in doing so, but it will still leave

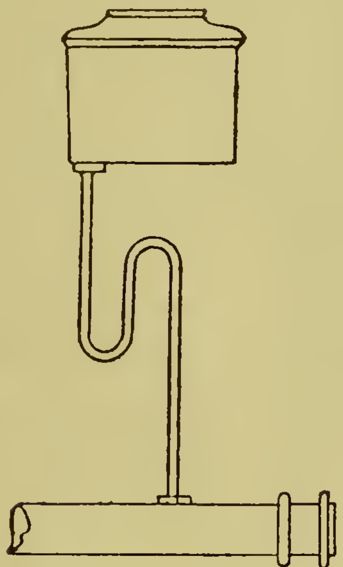

Fig. 33.

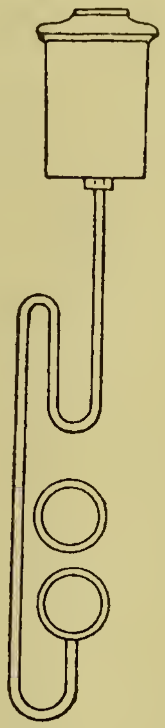

Fig. 34.

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extent under any circumstances without entailing a marked failure. Each pipe, whether there were many or only one, was a flow and return in itself. If vertical, the heated water ascended up the centre of the pipe, and the cold descended around close to the outer circumference. If they were carried in a slanting direction, the hot water travelled along the upper half of the pipe, the cold travelling back beneath it. It is worth any one's while testing this with a glass tube apparatus as already referred to. The action is very peculiar, showing again how very free from friction the water particles are which allow of contrary currents travelling alongside in contact with each other, yet absolutely free from the least trace of resistance. If this single pipe is carried horizontally or nearly so, the water does not circulate. To dip the pipe in the least degree is to form an impassable barrier.

some air locked at the upper bend. In the last instance that came to the author's notice the boiler and some branches had filled with water, but others failed to fill or heat, although every effort, short of a force-pump, was made to get the water to pass. When this double bend was removed the apparatus instantly filled properly and all went well. It is far better to do without this double bend, only putting a shallow dip, rising up into the return pipe as at Fig. 32 and as the lower part of Fig. 34. This is the recognised best and efficient plan.

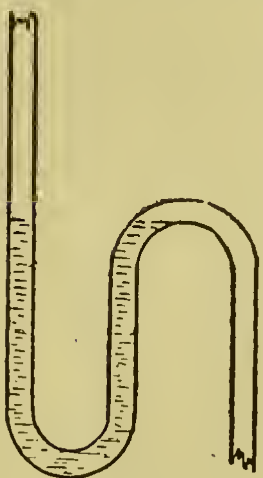
Fig. 35.

The cistern need never be fixed higher than from 12 to 24 inches above the level of the highest point in the flow pipe, so that the apparatus may quite fill. No more than this is required, as increasing the height of the position that the cistern occupies only adds to the strain upon the apparatus by the increased pressure of water. This will be more fully explained presently, when speaking of those forms of apparatus that are used for heating several floors of a building, and in which the question of pressure must have every consideration. The supply pipe (from the cistern to the return pipe) should be either ¾ inch or 1 inch, the latter for preference, as a great deal of sedimentary deposit sometimes occurs. It is an excellent plan to have a screw plug at the bottom point, as dirt may accumulate here very quickly.

It must be mentioned that when water is drawn off for various purposes a new and objectionable feature commonly presents itself if the water be hard (by coming from chalk strata), in the fact that the boiler gets incrusted internally with a coating of carbonate of lime, which, when of sufficient thickness, will cause the boiler plate to become fractured. This incrustation takes place in a minute form with nearly every apparatus (unless rain water be exclusively used), but no appreciable deposit shows itself unless the water is often changed. Each quantity of water, when subjected to heat, deposits a certain quantity of lime, which, although small, quickly forms a thick coating on the boiler plate when fresh water is frequently entering the apparatus. This subject is treated fully under the heading of "Hot Water Supply" for baths and domestic purposes.

When no water is drawn from the apparatus a ball valve is not always employed, owing to this appliance being apt to get out of order unless it has regular use, as already explained; and it is not always that the rule as to the size of the cistern being governed by the capacity of the apparatus is adhered to. Although the water expands when heated to the extent described, yet it only expands when first heated, and does not contract until the water is allowed to cool, which will be probably a period of six months at least, so that in many cases a small cistern is put just for filling purposes. The water, when first heated up, then overflows (passing away through the overflow pipe) as much as it will, after which no trouble is experienced until it is next charged full with cold water, which certainly does not happen in the winter. If there is a horticultural forcing house to be heated the fire may then be kept going all the year round.

For a simple apparatus consisting only of a few lines of pipe a very useful appliance is obtainable, which fulfils the purpose of a supply cistern and air vent combined, besides acting as a support and junction piece to the further extremities of the flow and return pipes. This contrivance is as Fig. 36, which shows its application clearly. It is a very useful thing.

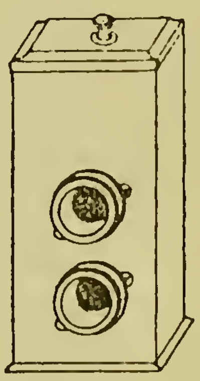
Fig. 36.

Rain water is most commonly used for charging any horticultural apparatus, and this is as commonly obtained from a ditch, pond, or collecting tubs. In all these places dirt, particularly vegetable matter, collects, and through a little carelessness the circulation has often been stopped by leaves, &c. For this reason it is very necessary to provide a means of emptying the apparatus by a pipe or tap fixed at a low point, so as to periodically flush out all sedimentary matter. This should be done regularly, and at least twice a year, otherwise the deposit quickly becomes sufficiently solid to prevent its being removed by a flush of water. It will then become necessary to take the pipes apart to clear them. The writer once saw a long length of pipe more than half filled with deposit caked hard, as Fig. 37. This accumulated by about three years' negligence.

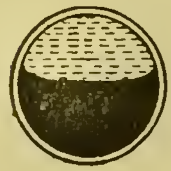
Fig. 37.

The expansion brought about by an increase of temperature has been spoken of so far as it concerns the water that fills the apparatus, but we have also to consider its effect upon the iron pipes which contain the water, as these are subject to this phenomenon. Although the increase is exceedingly minute in a single length of pipe, in long runs it may be sufficient to bring about a rupture somewhere, unless provision is made for the movement to take place freely and without strain.

Taking the extreme temperature of water from 32° to 212° (for the heat of the pipes is, of course, governed by the temperature of the water), we get a difference in bulk (or, in this instance, we may say length, as the increase in diameter is not appreciable) of 1 in 900, or, in other words, a 100-foot length of cold pipe would, upon being heated to 212°, be increased in length by $1\frac{3}{8}$ inch—not a great increase certainly, but sufficient to break some joints if no provision is made for it.* In a long length of pipe it is not sufficient that the extremity farthest from the boiler be clear to allow of this further projection. The weight or pressure exerted by the pipes upon their supports brings sufficient friction into play to prevent their movement until a considerable force is exerted, which in the meantime breaks the joints or does some other damage. It is therefore necessary (with long lengths) to rest the pipes upon rollers placed upon the brick supports. These may be short lengths of round rod iron or tube; or to secure neatness and stability an iron support with rollers can be obtained, as Fig. 38. This ensures free movement in expansion and contraction. This, however, is not sufficient by itself, for in the first place the upper (flow) and the lower (return) pipes of a main or a branch service expand to different extents, not being at the same temperature, and it will be seen that very awkward results must ensue if this is not provided for. Then again from a long main service there may proceed several branch services, and it would not do for these services (which are most probably carried off at right angles to the main) to be carried to and fro as the main pipe extends or contracts itself.

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* This does not apply to the screwed joints of wrought tube, but to the weaker joints of socket and spigot cast-iron pipes, as used in glass-house work. The remainder of this chapter deals exclusively with horticultural works.

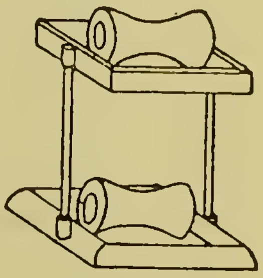

Fig. 38.

It therefore resolves itself into a necessity for providing not only that the pipes have freedom to move without binding on their supports, but this movement must be made local, so to speak, to various points in the apparatus. This is effected by the use of expansive joints, which, as their name implies, admit of a slight movement confined to the joint itself. Some of these joints permit of a telescopic movement, so as to prevent the extension continuing beyond the joint. More, however, will require to be said about these presently. The writer met with one instance where the expansion of a long length of 4-inch cast pipe pushed part of a new greenhouse wall out. This piece of wall had been built close up to the end of the pipes when they were cold.

CHAPTER IV.

EXAMPLES OF HORTICULTURAL WORKS.

Describing some examples of apparatus—A small apparatus for a lean-to greenhouse—Description of boiler—Arrangement of pipes—Water Supply, &c.—Another apparatus suited for a small conservatory—General description, position of boiler, &c., &c.—Description of another conservatory apparatus—A larger apparatus to heat two glass houses—Pipes in channels—General description—A large apparatus to heat a range of five glass houses with melon pits—Main pipes and their uses—Carrying mains in trenches—Branch services—Pits with bottom heat—Evaporating troughs—Capacity of air for moisture—Necessity of providing moisture—Position of pipes as regards roots, shrubs, &c.

In showing a few examples of the average description of apparatus that is to be met with, it must be clearly understood that the illustrations are not made with a view of providing designs to which all works can be erected. In the first place, it would probably be found impossible to adapt any of them to a new situation. Secondly, it is best and proper to work out and plan each apparatus that has to be constructed in a manner best suited to the requirements, not giving any particular thoughts to previous undertakings.

There is scarcely a doubt that of the many such works erected in England there are not two precisely alike, so varying are the circumstances that have to be taken into account. Still, those whose knowledge of such work is limited will find considerable assistance from the consideration of an apparatus practically complete and in position. A mere explanation of the principles governing the work is hardly sufficient, unless the reader has already had considerable practical experience.

Perhaps the most simple form of apparatus that is ever erected in connection with a boiler heated by solid fuel, is as

Fig. 39.* This is simply a flow and return service run along the side of a greenhouse as shown. It is very useful and much in demand for amateurs' works, as the pipe joints are simply made by unskilled hands. By the addition of bends the pipes can be carried around two or more walls of the house as required.

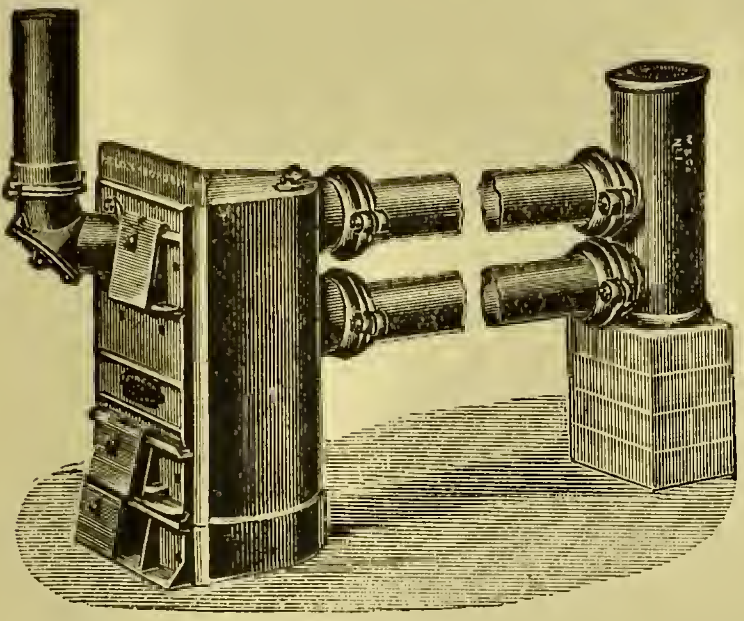

Fig. 39.

The illustration shows a somewhat recent innovation as regards the boiler. Previous to this form being introduced a brick-set boiler would have been required, or else one of the common independent form. In the latter case an objection existed in that the boiler had to be in a sheltered position, most probably in the greenhouse itself; in this case the presence of the boiler might not be so very objectionable, but in the majority of cases the unsightly flue pipe had to have a prominent position ; and in any case all stoking and attention and the attendant dirt and dust occurred inside.

The boiler illustrated is constructed in such a manner that it can be fixed in the substance of the wall itself, as Fig. 40, which shows a section of the wall with the boiler in position. By this arrangement the flue pipe is conveniently disposed outside, and all feeding, stoking and cleaning take place outside also. The pipe connections are, of course, inside as shown, and there is no need in this case to place the boiler out of the way or in an inconspicuous position. It can be placed (other circumstances permitting), so that the flue pipe can be carried straight up, and so save the cost and other objections that the introduction of bends and elbows brings about.

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* The " Loughborough " Boiler, by Messenger & Co., Loughborough.

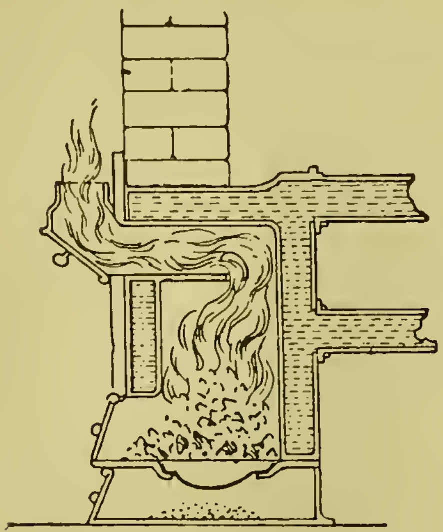


Fig. 40.

With this boiler there is but little heat radiated from the body of the boiler itself, as there would be if it stood wholly within the house. Yet even in this case there is little actual loss, as the boiler being imbedded in the wall, the poor conducting property of brickwork prevents the escape of heat, so that it remains in the water and escapes from the pipe surfaces only.

The other extremity of the apparatus is shown terminating in a supply and expansion box, as already recommended. This contrivance cannot be overvalued, as it is so neat, so accessible, takes the place of the supply cistern and its necessary connecting pipe, dispenses with the air pipe, saves a connecting piece at the end, and provides a substantial support to the extremity of the apparatus. This expansion box cannot usually be made self-filling with a ball valve, unless a small cistern be introduced. The expansion box itself is not large enough to take a ball valve, which requires an inconvenient amount of room. With an apparatus on a small scale, however, an arrangement for self-filling is not only unnecessary, but is a positive drawback, since the evaporation being so slow and the loss of water so slight, there is not sufficient work for the ball valve to keep it in order. As most people know, a ball valve works stiffly and "sticks" if not in constant use.

In an apparatus even as small as this the pipes should be made to rise towards the extremity, to assist the circulation and to permit of the free escape of air. This can be effected by making the brick base illustrated of sufficient height.

The use of this boiler necessitates starting the flow pipe horizontally, and as the total difference between the highest point in the flow and the lowest point in the return is but a matter of inches, the motive power is small, and no obstacles could well be permitted. It is not a boiler to recommend for large purposes if fixed in the way shown. If such a boiler be used below the greenhouse level, the flow pipe should be taken from the top.

Fig. 41 introduces another form of apparatus almost as simple in form as the last, but in this case it is supposed that a greenhouse or conservatory attached to a residence requires to be heated, and the boiler has to be situated in a cellar or basement room of the house.

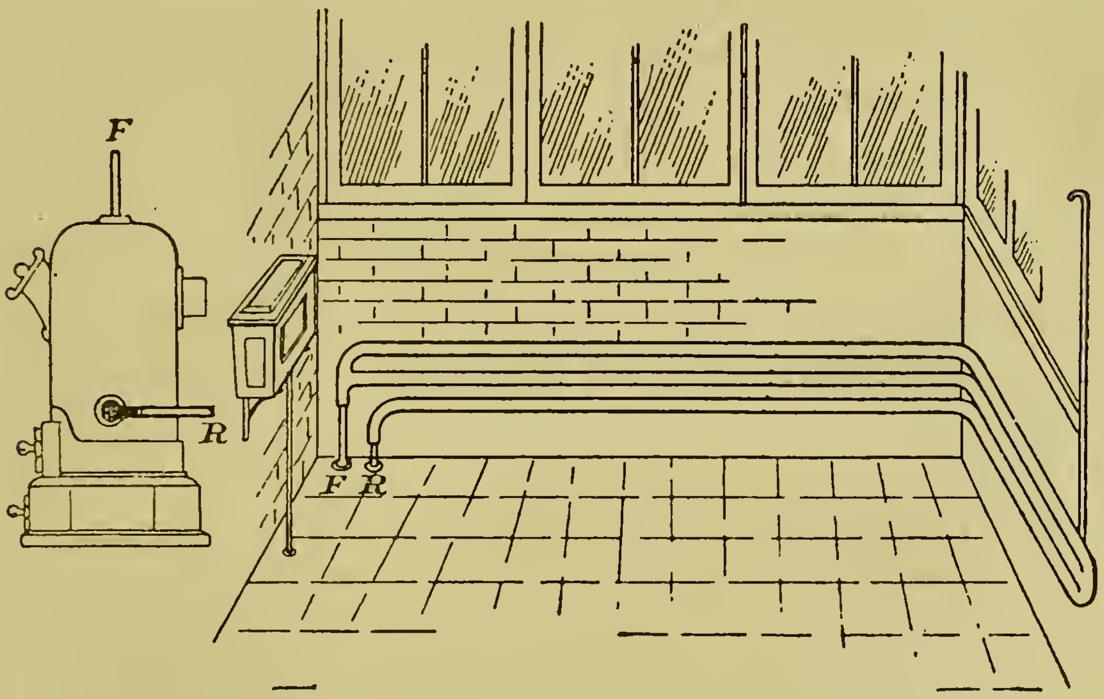


Fig. 41.

On the left-hand side of the illustration is shown a vertical independent boiler; and as it is in this case fixed below the level of the work, the flow pipe is taken from the top, the return entering the side near the bottom as usual. These vertical independent boilers are admirably suited for such a purpose as this, their shape making them convenient as to the room they occupy, the necessary fixing is reduced to a minimum, as they are quite independent of brickwork, and merely require to be connected to the hot-water pipes and to a chimney ; the latter is effected by a length of iron pipe and an elbow. They are made complete with fire-box, ashpit, feeding and stoking doors, and only require to be stood upon an earth or stone floor ; or if the floor be wood, a stone or concrete base has to be provided.

When fixing a boiler of this character it is necessary, to make it work effectively, that the flue pipe fit on the nozzle of the boiler tightly ; if it does not fit accurately, then let it be jointed with stiff putty (ordinary glazier's putty). Where the flue pipes are jointed together, and where the flue pipe or elbow enters the chimney, the joints must be sound and tight also, or a leakage of air will take place into the chimney with a proportionately ill effect. Every description of close fire boiler, or stove, requires this care in fixing, for *all the air that passes into the chimney should first pass through the fire.* If any other opening is left by which much air can pass in, the draught through the fire will be slackened and the boiler will not heat effectively. This will be spoken of fully when treating of chimneys.

A vertical-shaped boiler is particularly adapted for holding a charge of fuel which is delivered in through the feeding door situated at the top. Small horizontal boilers do not meet this requirement quite so well, although these can be fed from the top if required, but not so successfully as with the vertical shape. It will be readily understood that in such a case as this it is very desirable that the boiler should hold a store or charge of fuel sufficient to last a number of hours without attention, as in all probability the stoking may be done by a domestic servant. This end is met perfectly in a vertical boiler, as a medium-sized one will hold perhaps 1½ bushel of coke, sufficient for twelve, or at least eight hours' consumption ; and once the use of the dampers is understood, the temperature can be kept at a regular point continuously.

Every boiler of this description has the stoking and ash-pit doors arranged so that they can be used as dampers or draught regulators, but, unless carefully attended to, they do not bring about such regular results as a sliding damper in the flue pipe will do. Considering the small outlay involved, one of these latter should be provided in any case, especially as they are better understood by inexperienced persons.

Fig. 42 illustrates a sliding damper, this damper and its frame being made in and part of a length of flue pipe. This is the best damper to use. Fig. 43 shows in section what is called a throttle damper, being a disc of iron which by a handle attached can be made to lie at any angle to retard or to give free way to the draught. This cannot well be made to fit accurately, and a great drawback is that unless very nicely balanced it will not stay in the position it is placed at. It may, by the air current or draught, swing open (or close), and even if it fits well at first, wear, or exposure, &c., will afterwards make it work in an erratic manner.

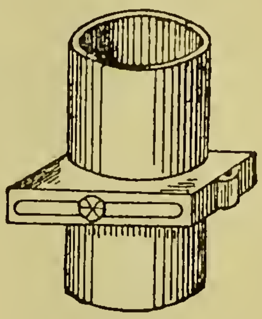


Fig. 42.

It may be mentioned here, although it will again be referred to, that in charging these boilers with fuel, some care is needed as to the size of the coke. When the boiler is filled up with coke it is with the view of providing a store of fuel at the top to automatically replenish that which burns away below. The automatic action is merely the gradual fall of the upper material by its own weight as the lower is consumed. Now every one knows with what tenacity pieces of coke will cling together, and if a small boiler is filled with pieces of medium size it will be found that in many instances it will refuse to fall freely, and although the lower part burns away, the upper part will wedge itself up and become "bridged," as it is called. The maintenance of the fire depends upon the regular and gradual fall of the fuel, and this is made certain by breaking the coke very small, that is, to walnut size for conservatory boilers in general. With large

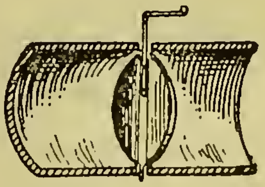


Fig. 43.

boilers, of course, a larger fuel is permissible, as the "bridging" does not take place so readily in a larger area.

On the right of the illustration Fig. 41 is shown an arrangement of pipes that may be in connection with the boiler just referred to. There is no need to show how the pipes are carried through the space that may be between the boiler and the greenhouse, as this will now be quite understood. They are simply carried by the nearest route, and care must be exercised to see that they do not dip down in their course anywhere, but are either carried horizontally or with a rising inclination. The connection of the pipes, however, at the boiler and at the commencement of the radiating pipe is shown, and each pipe marked, namely, F flow, and R return.

With this apparatus it has to be explained that the pipes between the boiler and the greenhouse do not by any means require to be large, certainly not the large cast pipes such as may be fitted in the greenhouse itself, as these would be most awkward to use, of greater expense, and quite unnecessary. The pipes between the points named need not be larger than 1 inch for a moderately small purpose, or 1¼ inch or 1½ inch if the conservatory is of good size and has a fair quantity of radiating pipe. Wrought-iron tube is used for these connecting pipes; it is easy of adaptation, is neat, and quite reasonable in cost.

The illustration shows three rows of pipes carried round two sides of the house, two flows, and one return. Let it be clearly understood that it is not always necessary to have three pipes, in fact it is not usual, two pipes only, one flow and one return, being generally sufficient for this small purpose. Three pipes are shown, however, to illustrate the ordinary method of adding the extra pipe if needed. For instance, suppose the conservatory to be used only as an adjunct to a ball-room, in which instance it might be filled with hardy shrubs and heated only as occasion demanded. In this case, three 2-inch or 3-inch pipes would give quicker and more economical results than two 4-inch pipes, as has already been explained. Or, supposing the conservatory to be a lofty one in regular use and having sub-tropical trees in it, then two pipes would probably be insufficient.

The pipes must be arranged that the extremity where the air pipe is situated is the highest point of the circulation.

When the pipes extend away around the house as these do, it is very necessary that they have support at different points. The nature of the support varies very greatly, different engineers having different views upon the subject. A very common method is to use brickwork, a small column being built up to and around the pipes as Fig. 44. This is a very good and workmanlike practice, but it is hardly admissible if the pipes are situated in a conservatory fully exposed to view, and recourse is then usually had to iron in some form.

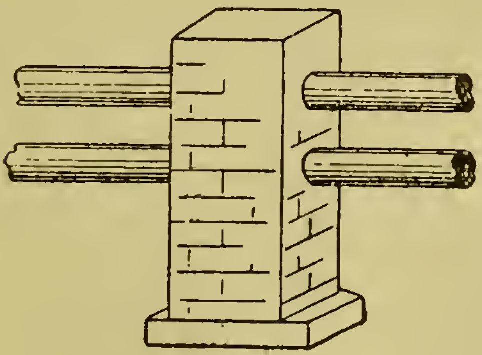
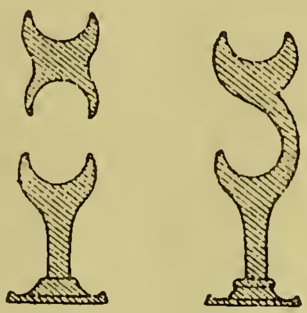


Fig. 44.


Figs. 45, 46.

A very good iron pipe-support is made, as Figs. 45, 46. These are made for any number of pipes one above the other, or they can be had suitable for two rows of pipes ranged side by side. Another form is simply a wrought-iron strap bent to the shape shown at Fig. 47; this, however, is only of use when the pipes run along a wall or partition, as the straps require to be secured to something at the back of the pipes, as will be understood. When the strap is used, a strip of wood is stood up between the wall and the pipes, as it is not desirable that the pipes bind firmly against the wall; in fact, they should hang in mid-air, so to speak, so that free radiation of heat from the whole of the pipe surfaces

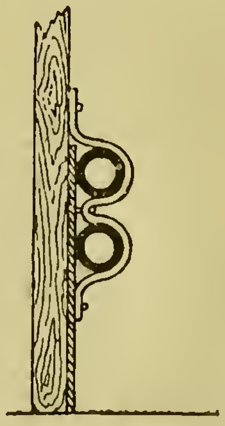


Fig. 47.

be assisted. Of course, any other form of support is permissible, provided it is of firm bearing, not likely to lose its shape or rigidity. Some care must also be exercised to see that the foundation to the support is good, or the weight of the pipes or some other cause may make the support sink and the pipes become uneven and out of level. This occasionally happens with brick piers, which are weighty in themselves, and if placed on the earth without care may sink to some extent.

The cold supply to this apparatus need only be provided for by a small cistern, filled by hand, as the loss by evaporation would be trifling, and insufficient to make the use of a ball valve at all necessary. This small cistern should be placed at the most convenient spot, out of sight if possible; or, if not, it may be fastened on a wall and decorated, but it need only be just above the level of the highest point of the flow pipe. It is never a good plan to place these cisterns more than, say 3 feet (a few inches is sufficient) above the point mentioned, as there is no need for it. It makes the filling a little more troublesome and more likely to be overlooked, as the want of water could not be observed so readily; and it increases the strain upon the joints and apparatus generally. (See Pressure of Water in Pipes.)

The cold supply pipe need not be larger than half-inch in a small apparatus like this, and it should be carried and connected into the return service with a dip in the pipe, as Fig. 32.

Although the dip in the cold supply pipe is necessary, and is supposed to appear in every apparatus that is filled from a cistern, there is one noticeable drawback, namely, the liability of this dip becoming choked with dirt which cannot be washed out or removed without taking the pipe to pieces. This is greatly aggravated by the practice of leaving the lid off the cistern, so that dirt and matter finds its way into it. This eventually reaches the dip where its further movement is stopped, and should rain water be used, there is even a greater liability of stoppage, as will be understood. This drawback is quite recognised, and occasionally preparations are made for its cure; but the only remedy that is at all worthy of recommendation is the provision of a screw plug at the lowest point in the dip, then a stoppage can be readily disposed of by the insertion of a wire or cane.

The next apparatus, Fig. 48, exhibits an arrangement differing from the last, as it is desired to heat a small glass-house or conservatory around all four sides. It cannot be arranged for the flow and return from the boiler to be connected at either of the extremities of the radiating pipes, and consequently the apparatus becomes one having, to all intents and purposes, branch services from the primary or main flow and return pipes. A certain care then becomes necessary to arrange for the branch in each direction to heat equally, or at any rate to work without a noticeable irregularity.

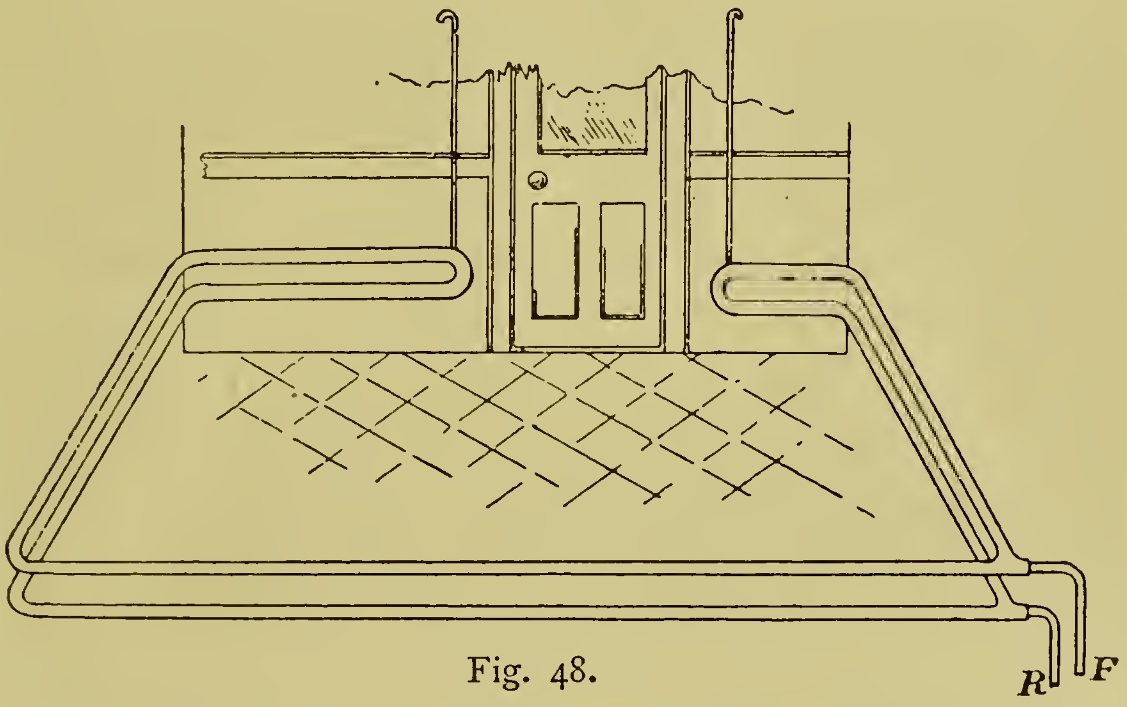


Fig. 48.

In this apparatus an unusual feature is introduced, it being seldom necessary to carry pipes around all four sides of a conservatory, but the illustration will serve to explain how these branch services should be treated, whether they extend as far as shown, or a less distance.

We may suppose this apparatus to be heated by a small independent boiler placed in a basement or some such point contiguous to the work, below the conservatory level. From the boiler to the radiating pipes there need only be a 1¼-inch or 1½-inch flow and return, connected and dealt with in every way as described with the last apparatus and in Fig. 41, and the pipes are marked F and R in the same way as in the preceding illustration.

We may suppose that this house is not very large, in which case, if the pipes are carried all round, 3-inch would be sufficient. This is governed by various circumstances, and recourse must be had to the rules and calculations provided to determine quantities and sizes for heating certain areas and for certain purposes. This subject is dealt with fully in Chap. IX. Should the calculations prove that a third pipe is requisite or desirable, this can be added as explained in the last apparatus, that is, two flows and one return. If it were thought best, one branch might have two pipes as illustrated, and the other three, that is, two pipes round one end of the house and three round the other.

It will be noticed that one branch has to travel farther than the other, as the primary flow and return does not enter at an equal distance from the door either way. Consequently, if some care is not used, there will be every likelihood of the shortest branch "taking the lead," as it is termed, that is, a rapid circulation setting up in the short branch to the prejudice of the longer one, causing the circulation in the latter to act sluggishly and to be of less heat-giving efficiency than it should be. In a large apparatus this is fully expected with some of the branch services, and provision is made for its proper regulation by means of throttle valves, the faster heating services being checked that the sluggish ones may attain a normal circulation, and so on, according to the wishes and requirements of the gardener. But in a small apparatus such as we are discussing, the use of regulating valves for this purpose is unnecessary, normal and sufficiently regular results being easily obtainable by giving a greater rise to the long branch than the shorter one, and this greater rise will be found to counteract the greater resistance that the increase of length offers.

At the highest extremity of each branch an air outlet has to be provided as shown, these being connected and carried, in one of the manners described on p. 49. The heating pipes have also to be supported well and securely, as described with the last apparatus explained.

The cold supply should be provided for and connected in the manner described with the last apparatus, and reference should be made to p. 53 and following pages.

As the work gets larger, attention must be given to the question of expansion, as although in a small apparatus the elongation of the pipes when heated is so trifling as to be unnoticeable, yet in a large one, where long runs of pipe exist, consideration must be given, as already explained, but it is only in what we may consider very long lengths that rollers and frictionless bearings on the supports are needed.

When pipes are supported on any of the iron stands referred to, there is so little friction that a moderately long length of pipe moves easily upon it as the expansive force, or the reverse is exerted. In brick piers the resistance by friction is greater, and with these, roller bearings for the pipes would be needed with a shorter length than if the supports were iron properly constructed with the bearing surfaces reduced to a minimum. But the fact of building a brick pier support around the pipes as explained and shown in Fig. 44, does not materially increase the friction over a plain brick pier which would not cover the pipes, as it will be found that once the apparatus is heated, which to a trifling extent increases the girth of the pipes, the brickwork will no longer firmly bind them, and any movement lengthwise will experience no special resistance.

The next form of apparatus, Fig. 49, is one in which the work is a step further than that just completed, and one in which we may suppose that there are two glass houses to be heated. These two houses join one another end to end, as is customary, but require different temperatures for different purposes, this being the primary reason, of course, that there are two houses instead of one larger one. Although these houses are spoken of in the plural sense, it will be found in almost all cases that the erection, in reality, is but one house, with a division in it, so that plants or fruit requiring different temperatures may each have the distinct treatment and an atmosphere which is most congenial to them.

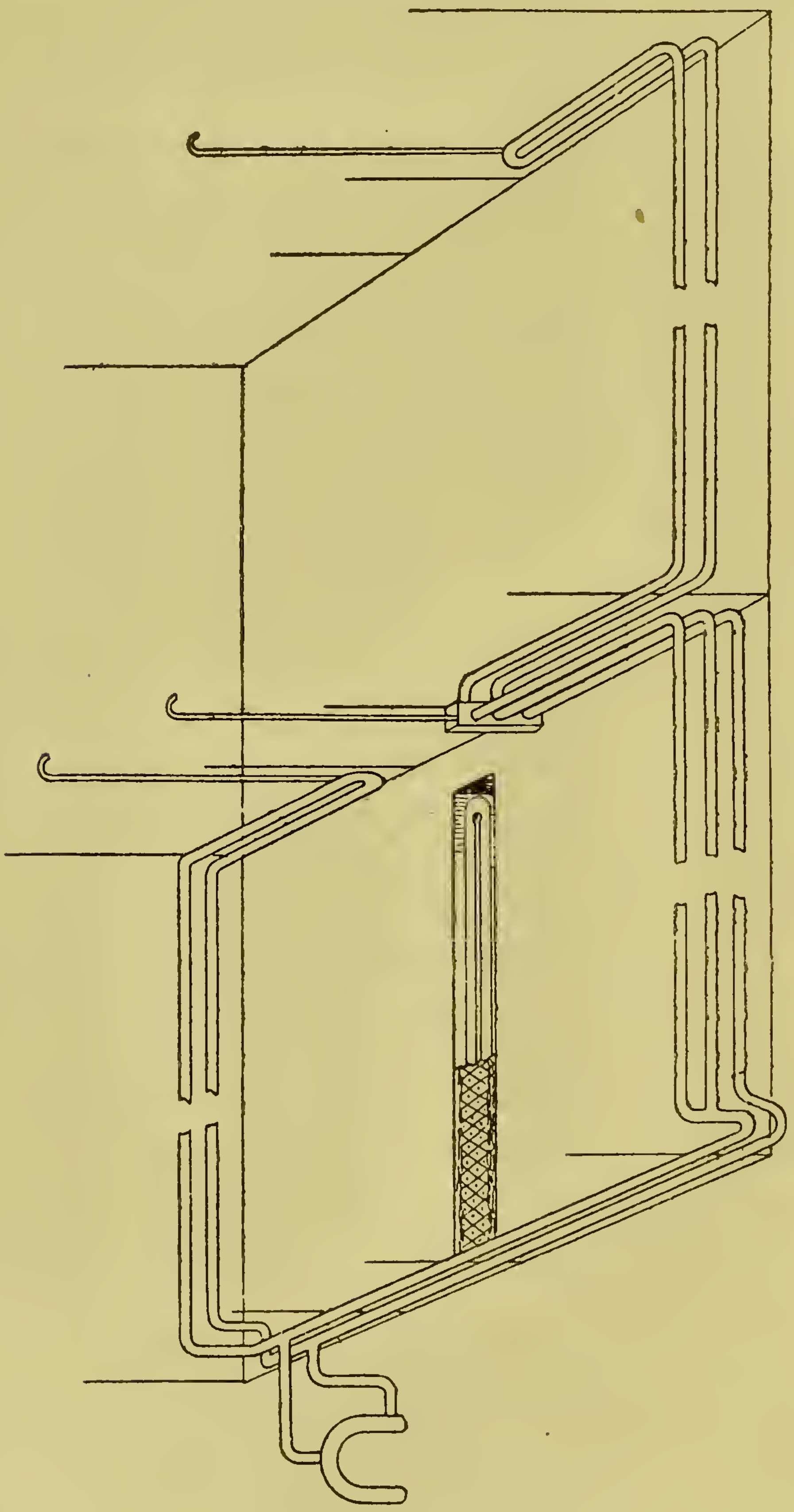


Fig. 49.

Plan of piping for two glasshouses adjoining. The quantity of pipe in the first one indicates that it is intended for a hot or tropical house. The second would be a greenhouse for half-hardy plants.

When the house is divided in this manner, the partition is commonly of wood and glass, but, whatever it is composed of, there is always (there may be exceptions) a doorway in it, and this interferes with the carrying of the pipes all round the house in anything like a simple manner. In addition to the doorway in the partition, we may, as a rule, expect to find a doorway in each end also, as shown. Of course, a doorway can be passed by dipping the pipes ; but this plan is very rarely resorted to in practice. It is not natural ; and under the best of circumstances it is in some degree prejudicial to success. Perhaps one of the greatest objections to it is that a dip in a pipe must prove a collecting point for dirt, and is rarely accessible for easy cleaning, even if such a provision is thought of. It is quite customary, with an apparatus such as we are describing, to carry the pipes around one-half of the house as far as the doorways will permit, this half being on the most-exposed side. As glasshouses are so often built against a wall, there is no objection to this arrangement, supposing a high temperature is not needed.

When a high temperature is required, arrangement is then commonly made to carry the pipes on all sides, and sometimes also up the centre, every available point having pipes if the house is for tropical plants or fruit, orchids, &c. Unless there is some very strong objection, it is always arranged for the hottest house to be nearest the boiler. It is exceptional for this latter arrangement to be impracticable, as upon the erection of hothouses every forethought and care is given to their being successfully heated, and, as before-mentioned, it is the regular thing for the gardener to superintend and to direct the works generally.

The illustration represents two houses, which we may suppose are of fair size, situated against a wall at the back, and having a passage-way through the centre, thus introducing a door at each end, and one in the division as shown. The boiler (of saddle or any customary shape, or it may be of the independent kind, although it is not usual) is fixed in a pit at one end near to the wall, or it could be on the other side of the wall if more convenient or desirable. The pipes in this case would be of full size where connected to the boiler, and continued of full size throughout the apparatus, 4-inch being the most suitable for work of this size and character, or 3-inch is permissible if specially wished for.

In this case the pipes from the boiler would need to enter the house below the floor level (the top of the boiler being 12 inches or more below this point). Immediately where they enter close to the wall they are branched, one branch instantly rising and being carried along the back wall (one flow and one return), and around as far as the middle doorway, as shown. The other branch is carried along inside the end of the house nearest the boiler, but still below the floor-level until the doorway in this end is passed. Pipe carried beneath the floor-level adds its proportion of heat to the total result, if placed in a brick or tile trench, and covered with an open grating.

When pipes have of necessity to be placed in channels or trenches, allowance must be made for lessened results due to absorption of heat by the surrounding brickwork, &c. The top gratings should be easily removable, as on no account must the pipes be allowed to get coated with dirt. Nor must dirt be allowed to accumulate around them, as they would then cease to distribute heat and might as well be covered over entirely without the expense of the trench and grating. Pipes in trenches, however carefully attended to, do not add to the heat of the atmosphere in an equal proportion to the pipes that are out of channels, and in calculating quantities this must be remembered and allowed for (particularly in church work, &c., in which exposed pipes are not usual). This will be found more fully explained in the calculating tables.

The illustration shows the branch (from the boiler towards the front of the house) carried in a trench along the full length of that end before it is elevated, but it will be understood that the elevation may, if desired, take place immediately it has passed the door. Immediately the pipes are brought up out of the channel they are carried along the front of the house, but upon the supposition that considerable heat is needed, the flow pipe is shown with an extra pipe added, this being usually required in a tropical house, and oftentimes when a house is of good size and cannot have pipes on all sides. Of course this branch could consist of four or more pipes if required.

This branch, as already explained, is carried along the front of the house as far as the division, and then inwards as far as the door. At this extremity the three pipes are reduced to two, which are carried through and back along the division in the other house, and there continued along the front and around the further end as far as the door, as shown. This second house we may suppose is for more hardy plants—a greenhouse—in which case the two pipes along the front and half-way up each end will usually give a sufficient heat.

At the point where the three pipes of the hothouse are reduced to two and carried through into the greenhouse, there is the possibility of unsightly work being introduced unless a box end is provided. This has a workmanlike appearance, and to some extent reduces the labour, it also forms a support at this point, where one is much needed. This box end is similar to Fig. 50, which shows three pipes entering at one side and two leaving at another side at right angles as would be required in this case.

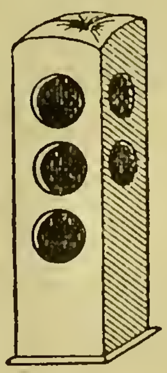


Fig. 50.

It must not be forgotten that throughout this apparatus (and throughout all that may be erected) the pipes must be fixed to have a gentle rise all the way from the point nearest the boiler to the furthest extremities. This has already been insisted upon, but it is desirable perhaps to repeat it.

In an apparatus that extends through two or more houses it is necessary to introduce stop-cocks or valves to regulate the heat, &c. In such an undertaking as we have now under consideration it may be supposed that the heat in the greenhouse may not be required during mild weather, yet in the hothouse heat may be necessary even during the summer, and in such a case a means must be provided to partially or wholly check the circulation beyond the partition. This would be effected by inserting stop-valves of some description (see pipes, fittings and appliances), in the two pipes immediately where they enter the greenhouse through the partition, as at Fig. 51, which shows the box end already referred to, but with the stop-valves attached to the two pipes just as they enter the greenhouse. The cocks are thus situated so that they effectually bring about the result desired, yet they do not, when closed, interfere in the least degree with the circulation in the first house. This is a very necessary consideration.

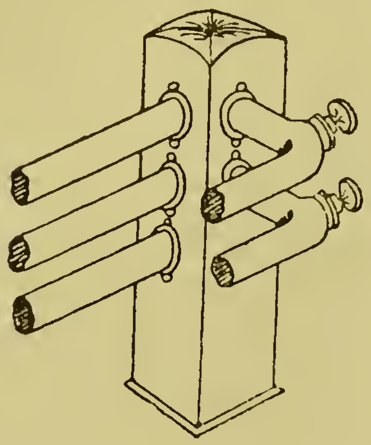


Fig. 51.

Stop-cocks and valves can be had in any size, but in such an apparatus as this there is no need whatever to have them of the full size of the pipe—2-inch will be sufficient without any risk of impairing the general efficiency. In a small undertaking, rapidity of circulation is of no moment, the extent of the services being limited, and a very rapid circulation would only tend to convey the hot water back to the boiler for no good purpose. The chief reason for using smaller stop-valves is the lessened expense, these articles being rather expensive if of good quality. The use of smaller stop-valves, however, has to be made with discretion, it lies chiefly with the distance that the pipes have to travel after leaving the boiler. If the work is of considerable extent every care has to be used to prevent the circulation being checked, for it is of no use having the water travel a great distance if it is barely warm when it arrives.* The same care has to be bestowed upon the question when the circulation from some cause is sluggish. Air vents are needed at the highest points as a matter of course. There is one shown at the box end at the division of the houses; this is necessary, as will be easily understood from the illustration.

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* The majority of gardeners are now rather averse to very extensive runs of pipe, preference being given to the use of a second boiler. More reliable results and oftentimes greater convenience is experienced.

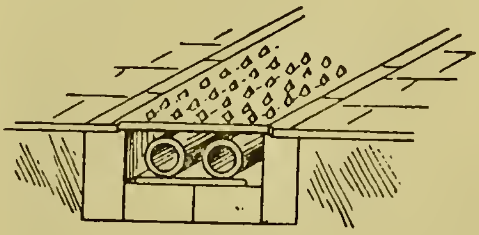

Fig. 52.

From the doorway nearest the boiler there is shown a trench and grating carried up the middle of the house as far as the division doorway. If it is thought necessary two (or more) pipes may be carried in this manner. This service is a branch from that carried beneath the floor level past the doorway. To keep the trench as shallow as possible, the two pipes should be carried side by side as in Fig. 52. This at any time gives better results than pipes one above the other, *if they are in trenches*, or in some cases the cost of trenching can be avoided, and the pipes run along in the open

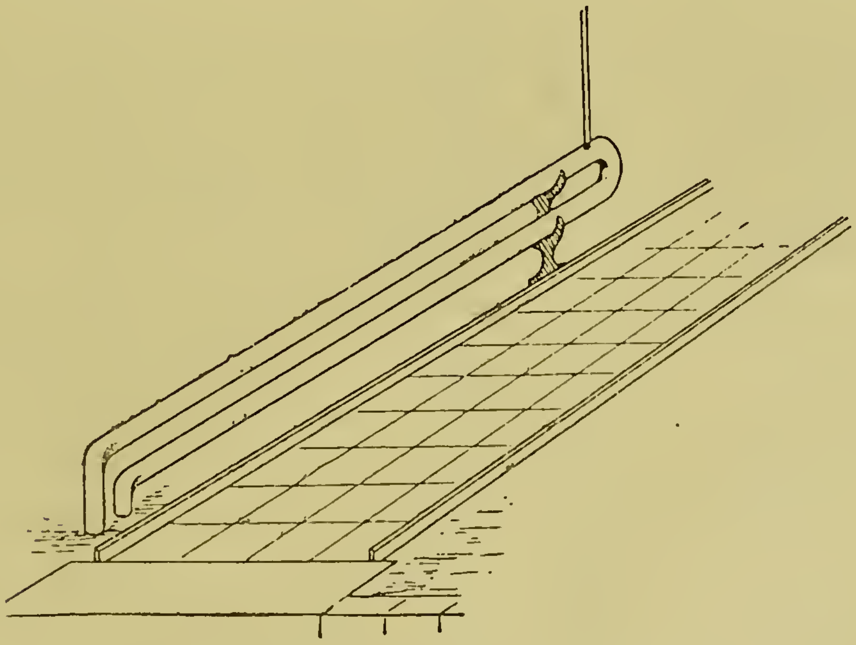

Fig. 53.

at the side of the path or footway as in Fig. 53. This service would require an air outlet at the extreme end, which of course is understood to be the highest point. This air pipe need not be carried up independently, it may join any other air pipe that is nearest to it, but as already explained it must not be allowed to dip down anywhere, but must ascend all the way.

The cold supply to this apparatus would be provided for by a cistern (with cover) in the usual way, the service pipe from the cistern being connected into the return at a near point to the boiler, or into the boiler itself. There is, however, an objection to taking the cold supply into the boiler in an apparatus like this, inasmuch as, unless special provision be made, some difficulty will be experienced in disconnecting it, should it get stopped with débris. The cold supply pipe in this case would not be larger than ¾-inch (some may use ½-inch), and this readily becomes stopped at the dip, if pond, rain or ditch water is used for filling. On this account it is desirable to keep the pipe clear of the brickwork surrounding the boiler, so as to be readily disconnected if desired, yet at the same time let it be attached to the return pipe at as near a point to the boiler as possible.

The branch that is carried round the back of the hothouse should not be given much rise, so that the circulation in this direction may not outdo that in the other direction, where it has more work to do. It is hardly necessary to insert stop-valves* in this back branch if it is kept nearer the horizontal than the other; this usually proves sufficient check in a moderate-sized apparatus like this.

We can now proceed to describe another form of apparatus as illustrated in Fig. 54,† which is upon a still larger scale than those already treated and which introduces a new feature that usually becomes necessary when more than two houses are heated from one boiler. This particular feature is

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* The names "stop-cocks" and "stop-valves" have hitherto been used indiscriminately, but the different uses they are intended for will be explained when treating these articles and appliances generally.

† These illustrations are of houses which are bounded upon one side by a wall. This is an arrangement usually sought for, but not always possible, particularly in large professional growers' grounds where there are ranges of houses side by side, necessitating the use of what are known as span houses, and which, on account of their width, usually have pipes carried along each side instead of on one side. An example will be given directly.

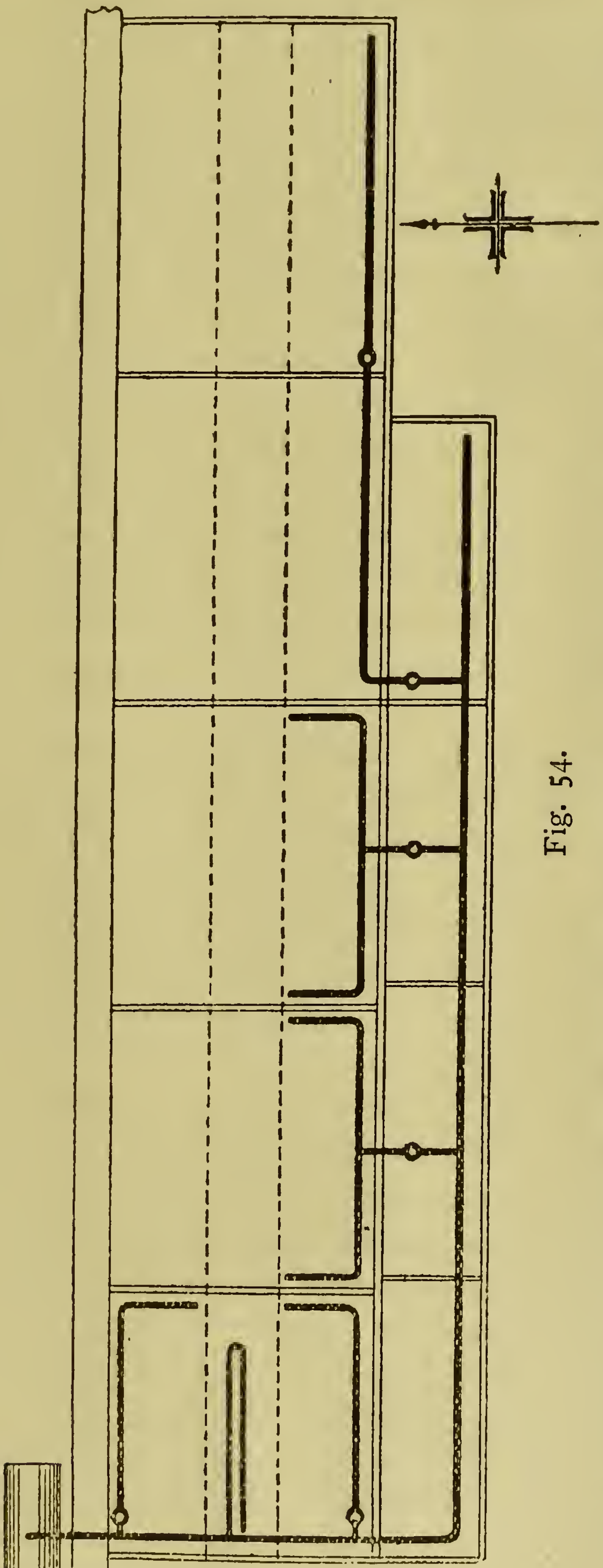

Fig. 54.

Plan of piping for a range of five glasshouses, and melon pits. Only the top, i.e. the flow pipes, are shown here, the return pipes being supposed to be underneath, and invisible on a plan drawing. The small circular marks indicate the positions of the stop-valves.

the "main" services, which are practically a primary flow and return, the general work being done by a number of branch or secondary services from them.

The real uses of these mains are twofold, firstly, if say four houses in a line are to be heated from one boiler it would be impossible to hope for anything like good results in the house furthest from the boiler if the circulation had to work through all the ramifications of the pipes in the first three houses. In fact, it is doubtful if any very good results would be obtained in the third house unless circumstances happened to be propitious. Secondly, if the pipes were continued from one house to the other as just described, it would be impossible to close the stop-valves in any one house without seriously interfering with the heat in the houses beyond it ; and it is absolutely necessary that each house have means to regulate its heat without in any way affecting the results in the others.

In the illustration, Fig. 54, the main pipes are shown carried along the front of the first three houses with the view of affording heat to some melon pits as depicted ; this is a very common practice, and there is no objection to it, but if the melon pits did not exist, then the main pipes might be carried up the middle of the houses in a channel, or better still, they might be carried along the outer side of the back wall (on the same side of the wall as the boiler).

In any case the main pipes should start as far below the level of the house floors as conveniently possible so as to afford a gentle rise along their full length. In addition to this, allowance has to be made for each branch service to rise a little after leaving the main, and to effect this it would be very desirable in an undertaking of this size to have the boiler-top 2 feet or more below the floor-level of the houses if possible. This, however, is very usually governed by the nature of the ground, as in some situations water is met with a very little way below the surface, and a deep boiler pit is out of the question.

If the boiler pit cannot be of ordinary depth by reason of water being found near the surface, it becomes necessary to use one of the several forms of shallow boilers which are made expressly for this emergency (see Boilers). Or, perhaps, the houses may be placed on sloping ground so that a rise is naturally required for the pipes as they go from house to house—this arrangement obviates the necessity of putting the boiler lower than is barely necessary to start the pipes horizontally into the first house.

The main pipes, in this latter case, need not be lower than the floor-level unless it is necessary to carry branches beneath doorways, &c.; but should the houses be quite level and extend a good distance, as these do, then it is desirable to start the mains as low as possible so as to give them as much rise as can be obtained in their journey to the extremity of the apparatus. When the houses are on rising ground this latter necessity does not occur, but it is the customary and generally desirable plan to carry the mains below the floor-level some little distance. In the apparatus under discussion the melon pits, through which the mains run, are a little lower than the houses they lean against; this is arranged and planned in concert with the gardener's wishes and ideas.

There used to be a controversy as to the correct size of main pipes, one suggestion being that the proper sized pipe to use was one having a sectional area equal to the aggregate areas of the branch services, that is to say, if there were eight branch services of 4-inch pipe, then the main pipes should have a sectional area equal to the combined areas of eight 4-inch pipes. It is needless to add that this would make some mains of enormous proportions. Theoretically, this argument carried weight, but in practice it was all wrong. The large size was most inconvenient and costly, the extra quantity of water contained in such large pipes was unnecessary and objectionable in other ways, and it was found that 4-inch mains were ample even for the most horizontal works. Even 3-inch mains have been found sufficient where a more than usual rise and fall have been attainable. In residence works where a deal of vertical pipe exists, the mains are frequently only 2-inch, and not always as large as that. The greater the rise and fall the less size the mains need be, but in horticultural work 4-inch is usually necessary, in fact it is the necessary size for this purpose.

The chief reason why a 4-inch main answers so well is that in a pipe of this size, which has but few bends, and a gradual rise from the boiler to the extremity, there must be necessarily a fair rapid circulation. This fulfils all that a main service is required to do, viz. carry a supply of hot-water to the required points quickly, and the cooled water back to the boiler in an equally short time. The branch services from the mains do not require to have a particularly rapid circulation, for so long as the heated water finds its way into the house, and then out again before it is absolutely cool, it suffices. It passes in with the view of dissipating its heat there, and no great gain is effected by its going in and out too quickly. A circulation can, of course, be too sluggish, but if the branch return, as it leaves the house, is found to be still hot the rate of circulation is sufficient.*

If the mains are carried up the centre of the house in channels, they should be covered with loose gratings (as explained in the last apparatus) so as to benefit by their useful effect, and in such a case allowance may be made for the presence of the mains in the house, when calculating the quantity of pipe needed, but it will be remembered that pipes in channels do not radiate more than three-fourths the heat that exposed pipes do.

If the mains were carried along the outer side of the back wall, they would then be carried in a brick channel, but a quite new feature is introduced here, as there would in this instance be no heat radiation required from them. Were they exposed, the heat so radiated would be wholly lost, without the least beneficial effect. Consequently means have to, or should, be resorted to with the view of conserving the heat within the pipes, and only permitting radiation to take place in the houses where the heat fulfils its useful purpose.*

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* It will be found that, with a branch of moderate length, the water passing back into the main return will only have lost about 15° of its heat.

The conservation of heat is a very interesting and important subject and requires every consideration, but it is not necessary to speak of it at length here, as it will be found fully discussed in Hot Water Supply, at the end of the volume. However, some necessary measures may with advantage be spoken of in this place.

If the mains are carried along the outer side of the wall, it may be assumed that the earth on that side is upon a level with the house floors, in which instance the pipes will have to be carried underground. This being the case it is usual to make a brick trench or channel, in which the pipes are laid, the channel being afterwards covered with slates and the earth filled in on top of these. This makes the pipes easily accessible if it is desired to expose them, *but it is also necessary that the space around the pipes in the channel be filled in with some poor conducting material*, otherwise it is just possible that a current or circulation of air may set in through the channel, and this would have a rapid cooling effect, as will be understood.

Of course a current or passage of air through the trench could be prevented by making it perfectly air-tight; but this would be a greater trouble and expense than filling it in, especially as good materials for this purpose cost so little.

Perhaps one of the best materials is dry ashes, and next to this dry sand. Silicate cotton is better, but a quantity of this would become expensive. Hair or even sawdust would do, but the former is expensive and the latter absorbs moisture. Ashes or sand are commonly used and answer well, and are most easy of application. Small wood fillets can be placed across the channel here and there for the pipes to rest upon, which will permit the material to get under the pipes. There need never be any fear in letting these pipes come in contact with wood, as no possible danger can arise.

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* Sometimes the mains are carried through sheds or rooms where mushrooms are grown, seed, gunpowder, or similar materials stored as required in a country house. The pipes are then exposed to afford the warmth required.

Branch Services.—In this apparatus, as in the last, the mains after leaving the boiler are carried across the end of the house below the floor-level in a brick trench either covered by a grating or filled in. In the first house, which is assumed to be for tropical plants, there is shown a branch of three pipes, two flows and one return, across the back of the house and around as far as the doorway in the division. Also a branch of a similar character across the front of the house and around to the division doorway; and a branch of two pipes carried up the middle beneath the floor in a channel. This is usually ample for a tropical house, but the reader is again reminded that the sufficiency of pipe is determined by calculation as described in the table of quantities.

The pipes in this house (and throughout the whole apparatus) will be 4-inch, and an air-vent would be needed at the highest (i.e. furthest) extremity of each service.

In the second house, which is reserved for a certain kind of grape and for strawberries, it will be found sufficient to carry the pipes across the front and around each end as far as the division doors, these pipes being connected to the mains by a branch brought across the melon pit as shown. In this grape-house there might be four pipes, two flows and two returns, this particular grape being supposed to require a higher temperature than that in the next house which has a pipe less. It does not, however, fall to the hot-water engineer's lot to decide what temperature a certain variety of fruit requires; this is determined by the gardener, who (it cannot be repeated too often) decides all such questions and dictates generally.

To this second house there would need to be a pair of stop-valves; one in the flow, and one in the return, where the pipes pass across the melon pit before they enter the house, and before the branch is increased to four pipes. No valves were mentioned in the tropical house, it being a somewhat disputed question as to whether they are needed there, many gardeners affirming that no regulation is needed in that house, too much heat being impossible, and others having an opposite opinion. If cost is not of primary importance, it is best to have valves in every branch that is of the least importance. In this second house there would need to be the usual air vents at the furthest extremity of each end of the branch, that is the end by each doorway.

The third house is supposed to be devoted to grapes of another variety requiring a lower temperature, and possibly a slightly different atmosphere, which renders it difficult for the two varieties to be grown together, and so necessitates a separate house to each.*

In this case there would possibly be two flows and one return running along the front of the house and up each end to the doorways, the necessary air vent being provided at each of these ends; but in this case we may suppose that the roots of the vines are differently disposed, and instead of being situated at the back they are brought through the front of the house, the roots themselves being in the earth outside the house, but the stem or trunk being trained through the front brickwork into the inside, where the whole of the vine may be said to exist, except the roots. This is a very common practice, the famous vine at Kew being trained in this manner, and it is to be presumed that it gives favourable results, although it interferes somewhat with the disposition of the hot-water pipes.

If the house abuts against a wall, it may be supposed that the side nearest the wall is in least need of heat, or, rather, it loses its heat less quickly; and if one side of the house only is encircled with pipes, then it should be that side which is most exposed, and this would be the side furthest from the wall. If, however, the vines enter through the front, the pipes may then be carried along the wall side or they may be run along the exposed side, but terminating and returning each side of the vine trunk. Or the pipes may be run up the centre of the house alongside the footway. Stop-valves would have to be placed in the branch flow and return as they cross the melon pit, as explained with the last house.

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* In a range of glasshouses there is generally included an early and a late vinery.

In the next, which may be termed a greenhouse, three pipes—two flows and one return—across the front only, usually suffice, these being connected from the main, as before described, with the necessary stop-valves and air-exits. A greenhouse is generally used for plants, sub-tropical productions, orange-trees, &c. ; but the term greenhouse does not convey any very exact meaning, and consequently the quantity of pipe will be wholly governed by what the gardener intends stocking the house with.

The last, and which would be called a cool-house, may have two pipes only, carried along the front. This house would only be used for wintering trees or hardy plants, or for apricots, tomatoes, &c., that only need to be preserved from frost.

This house wlll not require to be in direct communication with the mains, and if the pipes are continued through from the greenhouse this will be found quite satisfactory, but there will have to be an H-piece with valves, as Fig. 55, just at the division between the houses ; this provides a means of closing off or regulating the heat in the house. An air-exit must be provided at the extremity of the two pipes. At this point the apparatus reaches its highest level.

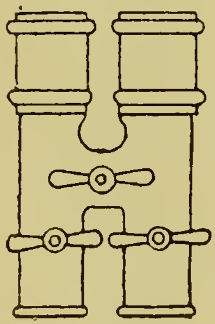
Fig. 55.

The pits along the fronts of the houses, which are generally devoted to melons and cucumbers, are heated by the two main pipes which pass through their whole length, and also by the branch services which cross them. There is, of course, no means of shutting off or regulating the heat of the mains except by the regulation of the fire under the boiler, so that if the pits are at too high a temperature (they are never too cool with two 4-inch pipes through them), recourse is had to the lights or covers, which are opened to a greater or less extent, and so permit the heated air to escape,* and thus reduce the temperature within. These pits are lower than the houses, this being arranged in the construction, and gives every facility for the gentle ascent of the pipes from beginning to end.

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* It takes but a very little time to reduce the temperature of a pit, as

This apparatus would consist wholly of 4-inch pipes, supported by brick piers or by iron stands ; brickwork is most usual, although of the two iron has the best appearance and as much solidity. In any case, the foundation or ground upon which the supports rest must be firm, and have no tendency to sink in the least degree.

In another example, Fig. 56, it is supposed that a doorway comes in the back wall severing the run of the houses, or perhaps an additional house has been added on the opposite side of the doorway to the two existing houses. The boiler has to be on the other side of the wall which the houses are built against. As only two houses come together, long mains are dispensed with.

It is not, of course, absolutely necessary that the boiler be at one extremity of the houses to be heated ; in fact, by placing the boiler somewhat centrally, we may occasionally gain a little in convenience. Here again, however, we have to act agreeably to the gardener's planning ; no one is more capable of deciding such questions, but let it be understood that he is not to be appealed to in everything, the worker must have judgment of his own. At the same time, if there is a gardener on the premises, as there nearly always is, he must be consulted and his wishes carried out. In most cases the gardener superintends the work to a very considerable extent, and everything is done in accordance with his views ; indeed, many gardeners are highly skilled in planning such works.

In this arrangement of houses (Fig. 56) it becomes necessary to have two sets of mains, so to speak ; that is to say, the main flow has to be branched off in two opposite directions immediately it leaves the boiler, or, if desired, two distinct

immediately the cover is shifted the warmed air, by its rarefaction, is displaced by cold air, and a change in temperature is directly effected.

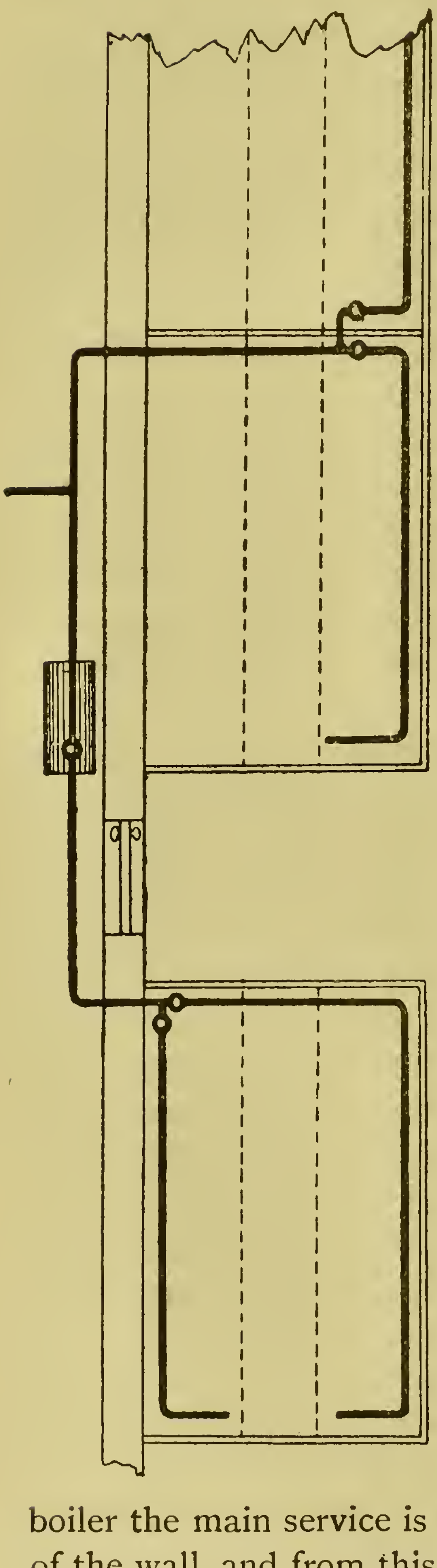

Fig. 56.

flows could be taken from the boiler direct. In either case the pipes should be 4-inch, no larger nor smaller size becoming desirable by either arrangement.

In the illustration it is supposed that there is one house on the left of the doorway, and two or more on the right, and that no pits exist in the fronts of the houses. In this case the main to the left may be carried along the outer side of the wall, below the ground level (thus clearing the doorway), until it reaches the nearest end of the house. It then passes through the wall inside and is disposed of for heating purposes in some one of the various ways already spoken of, or as circumstances or judgment may dictate. The return pipe would be brought back into the side of the boiler, and although the two main flows may be branched from one pipe, there is no need whatever for the returns to be joined in any way. The two returns would come one into each side of the boiler, this arrangement giving the most uniform results generally.

On the right-hand side of the boiler the main service is shown carried along the outer side of the wall, and from this the branches are taken through the wall into the houses at the points desired ; this has been fully

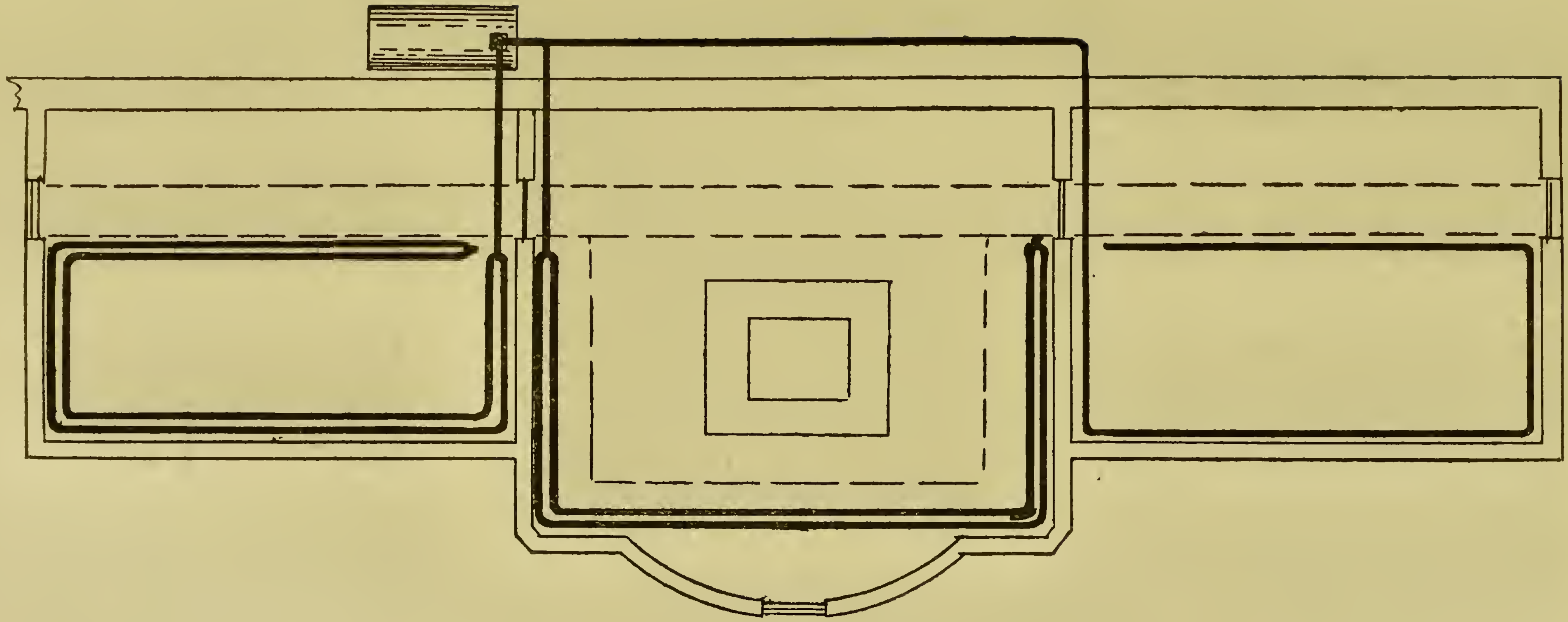

Fig. 57.

Plan of piping (showing upper, flow, pipes only) of a range of houses as might appear in the grounds of a large residence. An Early Vinery on the left; a Late Vinery on the right; a span-roofed Conservatory in centre; the whole carried along a back wall. In the Vineries the pipes are carried around the beds; in the Conservatory the pipes are less conspicuously placed beneath the stagings.

described also. From this last main service there is shown a branch or supplementary main carried off at right angles for the purpose of heating another house, which we may suppose is a few yards away. This can be done in the way shown, or, supposing this service had its starting point anywhere near the boiler, then it might be taken direct from the boiler itself.

It would be rather necessary to have stop-valves in each pair of main pipes (as well as in the branch pipes where usually needful) with the view of regulating the circulation in each direction. It would also be very necessary to carry and surround these main pipes, to prevent loss of heat, in the way described (p. 83), as it is supposed that they are wholly underground. And there would need to be the customary air-exits, and other provisions already spoken of fully in the previous works described in this chapter.

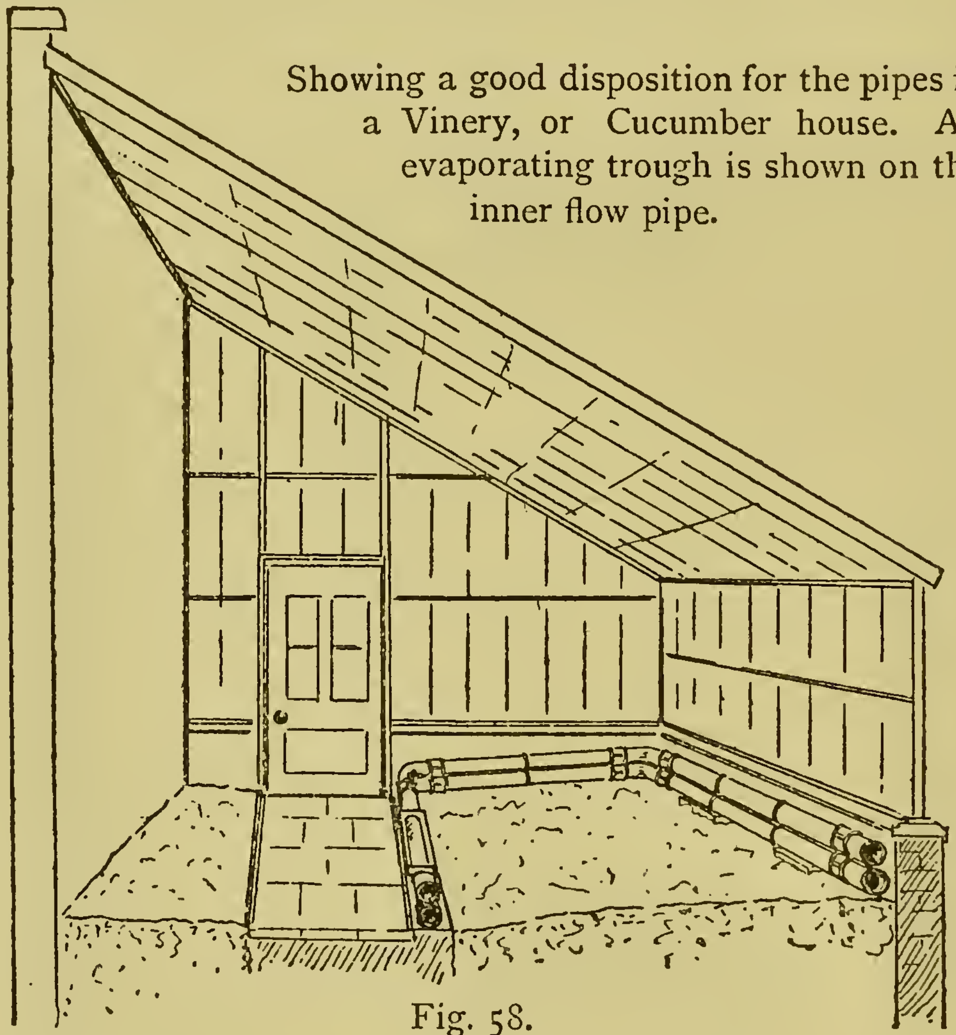
Showing a good disposition for the pipes in a Vinery, or Cucumber house. An evaporating trough is shown on the inner flow pipe.

Fig. 58.

The example given in Fig. 57 represents (in plan) a building commonly seen in private grounds, generally of an ornamental character and appearance. The centre house would probably be higher than the side houses, and in some instances have a dome roof. In this case we may suppose it has a span roof, and the houses each side, devoted to grapes, are of the lean-to kind, there being a brick wall run along at the back as shown. An Early Vinery on the left is shown with four pipes carried round the bed, and a Late Vinery on the right, with two pipes carried in the same way, as Fig. 58.* This way of running the pipes is commonly practised when plants or vines are rooted in the soil of the house. Not only grape vines, but cucumber and tomato vines, admit of this arrangement. The centre large house would probably be used for flowers and plants that make a show, and which are cut for the table. The quantity of pipe required will rest with the gardener's plans as to what he intends stocking the house with, or the heat he thinks will best suit his purpose. The disposition of the pipes, however, will undoubtedly be as shown in plan at Fig. 57, and in section at Fig. 59. The pipes are then out of sight under the staging which carries the plants, and do not make an ill appearance. In works of this

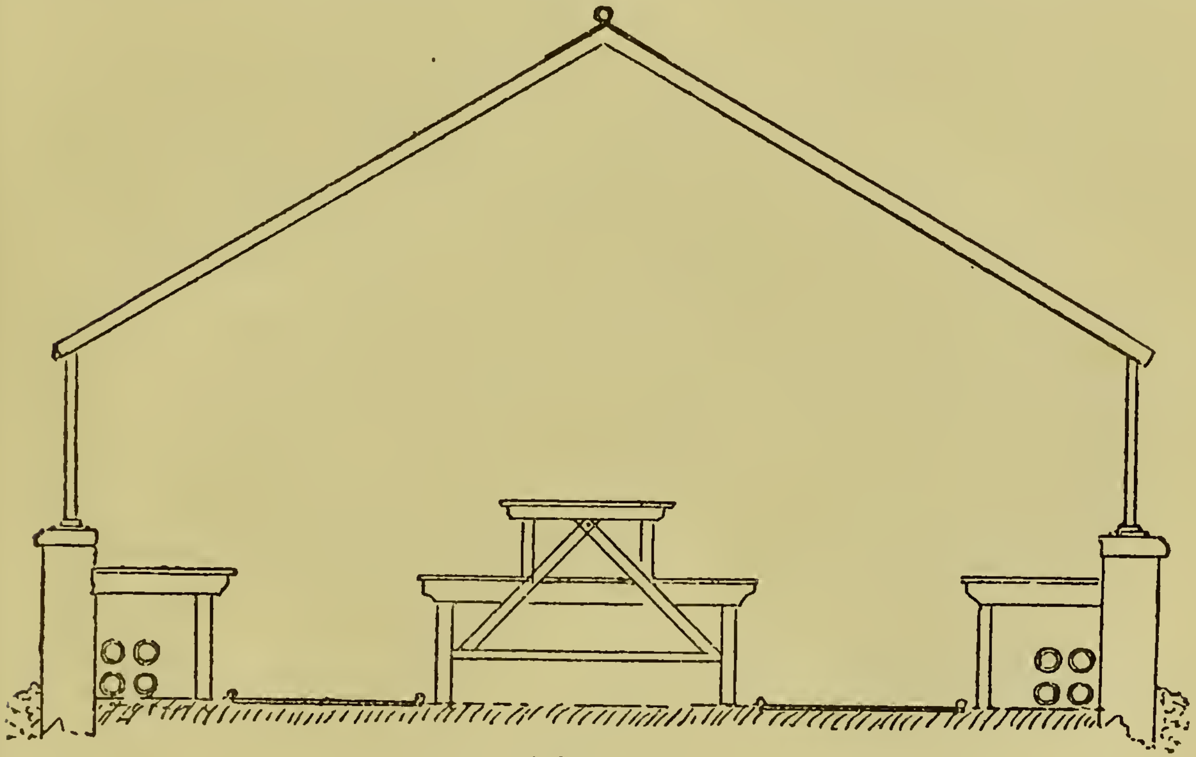

Fig. 59.

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* In Fig. 57 only the upper pipes are shown.

kind, in which the glasshouse is used much as a conservatory, appearances must always be considered. It is highly probable that, in front of the stages, ferns or creeping plants would be disposed to aid this result.

The boiler pit is shown situated on the other side of the wall, somewhat centrally, yet admitting of mains being very conveniently run. The mains would be 4 inches and the branches 4 inches also. If the houses were not large the whole of the pipes might be 3 inches, but not smaller. As in the previous examples, the mains are run below the floor line of the houses, and each branch would have a valve conveniently situated for use. A gradual rise to all the pipes, and the provision of air pipes at the highest points, will be the same as previously explained.

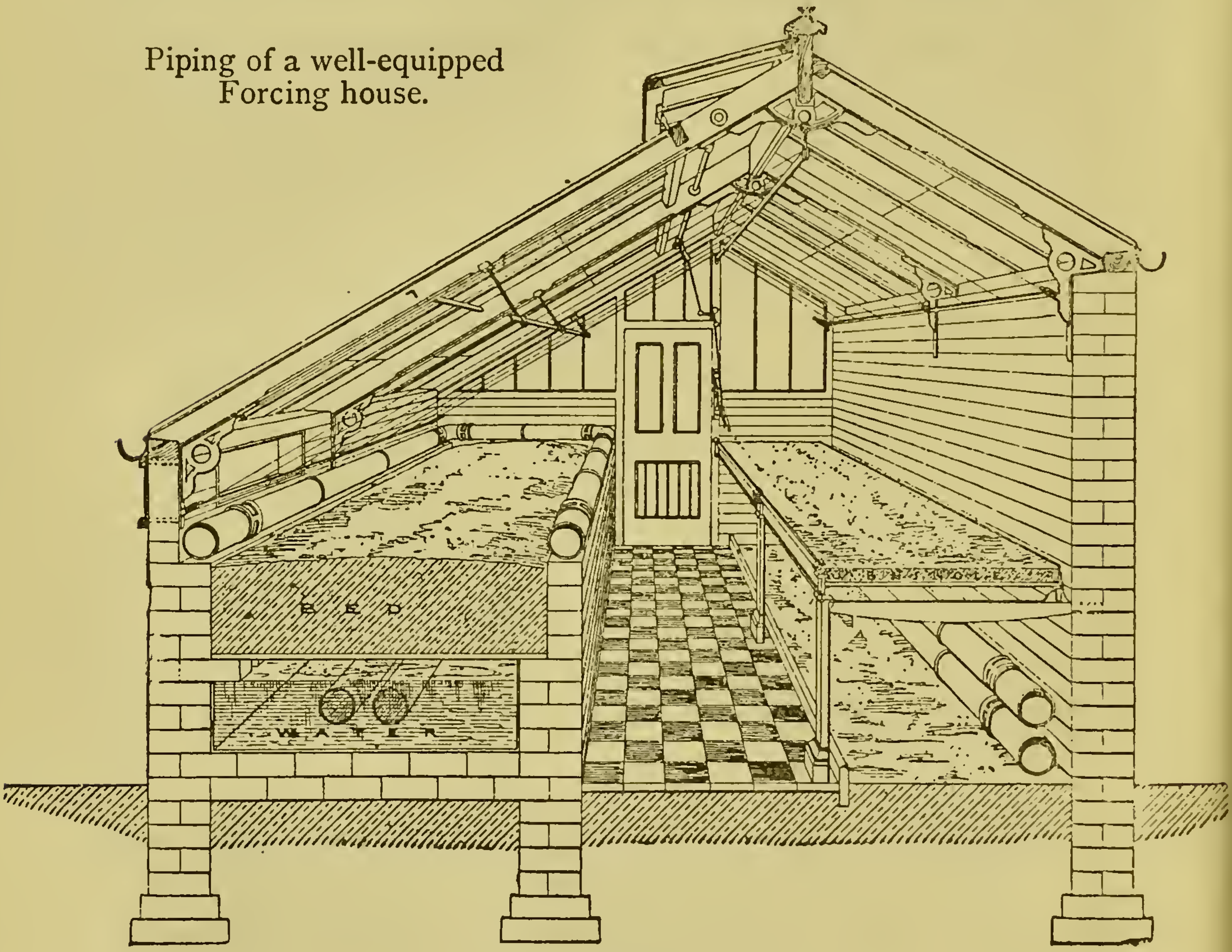
Piping of a well-equipped Forcing house.

Fig. 60.

In Fig. 60* is given the disposition of the pipes in a well-equipped Forcing House. On the right is a bed for plants or vines to be rooted in, and beneath this is a water tank having hot pipes running through it. This provides for the air receiving a full volume of water vapour to render it humid, and also providing a bottom heat to the bed above. Around this bed on the top is carried one 4-inch service. On the left is a shelf or stage to carry pots. This stage has about a 2-inch layer of fine gravel on it, and beneath, against the wall, is a 4-inch flow and return branch, as illustrated. In a dwarf house of this character, and having a brick wall on one side, the quantity of pipe shown would give a rather high temperature, such as is required for forcing or for tropical productions. The quantity of pipe for a given temperature, however, is settled by measurement and calculation (see Quantities for Horticultural Works).

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* Furnished by Messenger & Co., horticultural builders, Loughborough.

In many hothouses an independent pit will be erected, with water pipes beneath it, to be used for forcing purposes, also in the cultivation of pine-apples, &c. This description of pit must not in any way be confounded with a pit that is a space dug out of the earth: those now referred to stand above the level of the hothouse floor. There are two or three arrangements for heating them;* one being as Fig. 61, in which the earth rests upon a kind of false bottom full of perforations, and the pipes disposed beneath as shown. In another case the pipes are laid within the pit at the bottom, as in Fig. 62, these being first covered with clinker, large stones, or broken bricks, and the earth being placed on top of this large material. Sometimes the lower part of the pit

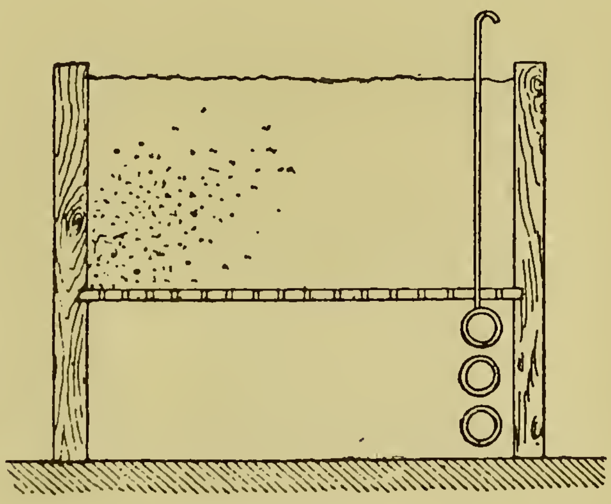

Fig. 61.

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* By adopting hot-water pipes for this work, the use of manure and such heating matters is avoided, with all the consequent inconvenience, irregularities, &c.

contains water, the earth resting on a perforated bottom above it, as in Fig. 63, the pipes passing through the water as shown. The part containing water is usually made of brickwork well cemented to render it water-tight. It will be understood that when first starting the apparatus the water in this tank robs the pipes of heat very rapidly, but once the water is hot it is kept in that condition with very little expenditure of heat. This arrangement is also adopted for heating a tank of water for watering purposes, but in such a case there are usually valves, so that the water does not always circulate through, owing to the cooling influence it would have as the water in this tank is drawn off, and replaced with cold. In Figs. 61 and 62 air pipes would be needed as shown, and in Fig. 63 an emptying tap and a filling tube are required for the cistern portion as well as an air pipe to the circulating service. The filling tube to this latter pit should be of good

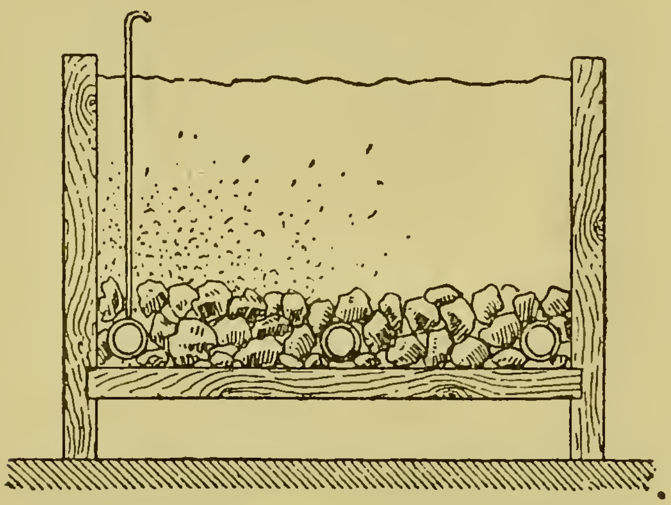

Fig. 62.

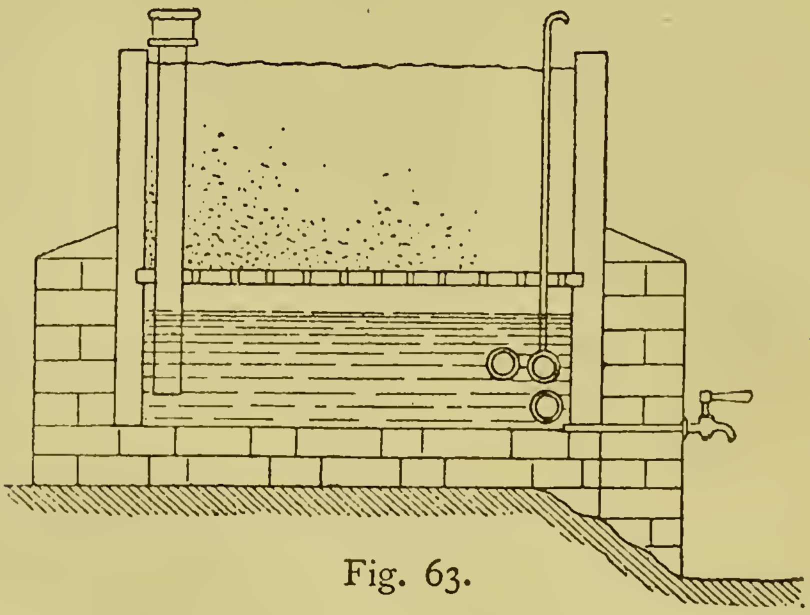

Fig. 63.

size, so as to allow of the free escape of air as the water poured in displaces it ; a 3-inch pipe might be used.

Three pipes are usually sufficient for these pits, but in Fig. 62 the pipes are sometimes carried round the pit, and a cross pipe used as in Fig. 64. Four-inch or 3-inch pipes are used for these.

A very necessary feature in nearly all glasshouses, whether the hottest or the coolest, is what are known as evaporating troughs, or trough pipes (see fittings). There are three recognised forms of these ; one being as Fig. 65, in which the trough is cast on and forms part of the pipe itself ; another is as Fig. 66, which is a cast trough laid or resting upon an ordinary pipe. Both of these require to be filled by hand periodically. The third kind is an open channel pipe as Fig. 67 ; this, however, must be fixed in a high position or it will overflow, and it is hardly worthy of mention, as it can so rarely be used and has no special advantage.

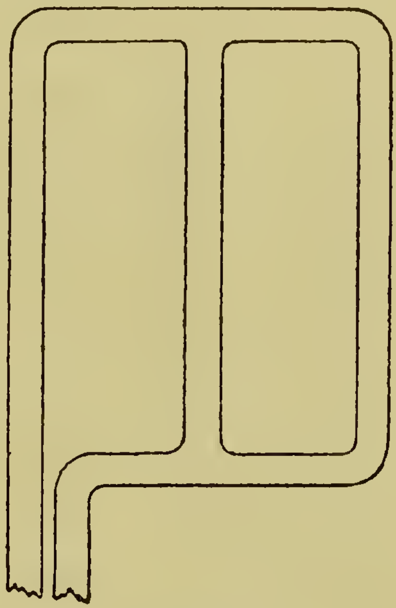

Fig. 64.

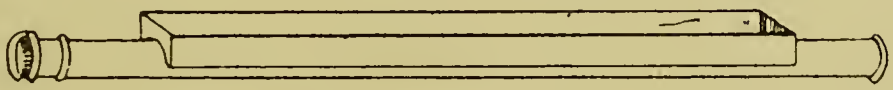

Fig. 65.

There is no recognised rule as to the quantity of these pipes to be used in certain houses ; it is usual to put two or three in all houses as they cost but little extra, and the gardener need only use what he thinks proper, and usually this is one of the details of a hot-water apparatus that has to be carried out according to the gardener's wishes in the first

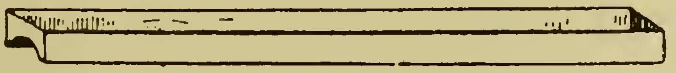

Fig. 66.

instance. The advantage of having a sufficient quantity is that the houses may be used for different purposes at different times. At certain periods of the year greater moisture is needed than at others, and again there are times when the troughs are used for evaporating other liquids than plain water. The movable trough, Fig. 66, is very convenient, and occasionally these are made in zinc for temporary purposes.

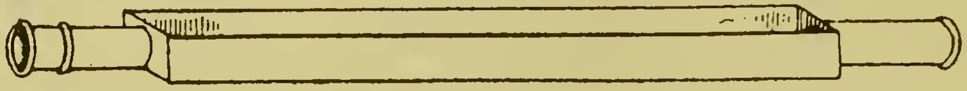

Fig. 67.

The object of these troughs is to provide a sufficient moistness to the air, to saturate it more or less, and make it humid. It is a well-known fact that the air at all temperatures holds a certain amount of water in suspension, but it is the least quantity with the lowest temperature, and the greatest quantity with the highest; air having an increasing capacity for holding water in suspension as the temperature rises. As an instance, we know that the morning dew, and the freshness imparted to vegetation by moisture, disappears gradually as the sun gains in power, and everything has a different appearance at noon to what it had in the early morning.

This result is entirely brought about by the transference of moisture from the earth and vegetation to the air. We have exactly the same result in a hothouse, which, as it becomes heated, and its water-absorptive power increases, abstracts all the moisture it can from the plants, &c., which will suffer in proportion; but by providing evaporating troughs the air is saturated as the temperature increases. Indeed, it is easy to over-saturate the air so as to have the peculiar dampness and heat that are characteristic with luxuriant tropical vegetation.

In the hothouse and for ferns, moisture is in great request, but in a grape-house the air must be drier, especially at certain times of the year. The gardener can generally judge of these things to the best advantage, but in any case it will be understood that evaporating troughs are provided to fulfil a natural atmospheric law, and that without this precaution plants would be robbed of moisture as well as the earth in which they grow, and their end would be quickly brought about. When we artificially heat a greenhouse, we must artificially provide for the additional moisture that the warmed air has increased capacity for, otherwise unnatural results must ensue.

In every illustration of hot-water heating apparatus devoted to horticultural work, the pipes are shown running along the walls hither and thither, apparently without regard to situation, or as to how they may affect any roots (grape, peach, apricot, roses, &c.) that have to be carried and supported against the walls or elsewhere. It is impossible to suppose that the roots can conveniently be disposed to suit the pipes, consequently recourse must be had to the gardener to settle this question also. It is not necessary to entirely alter the plan of the pipes on this account, but arrangements must be made that the pipes do not come in anything like contact with the stems or trunks of the plants.

Of course all this should be settled before commencing the undertaking, and whether the work be done to estimate, or contract, or otherwise, everything is planned out and arranged beforehand ; at the same time it is possible for such a detail as this to be overlooked. The average gardener will permit of pipes coming as close as 6 inches to grape roots, if it is necessary, and if the pipes are kept, say, 4 inches below the lattice that supports pots, it will suffice ; but it is not usually permissible to have them closer than this. The examples given show the methods of running pipes generally adopted for different purposes and under different conditions. The plans can be varied when necessary, but in the case of a lean-to house good results could not be expected if the pipes were all disposed on the wall side ; and in the case of a span house, the pipes must not all be near the centre, or heat at the sides will be very unsatisfactory. If the heat is diffused near the glass surfaces, where the greatest loss occurs, the best results will be had, for the centre of the house and brick walls lose so little warmth.

CHAPTER V.

IRREGULAR FEATURES IN HORTICULTURAL WORKS.

Dipping pipes below doorways and other obstacles—Its effect upon the motive power and general efficiency—Velocity and its effect—Practical *v.* theoretical results—Retrograde motion—Calculations as to "dipping" pipes—Other phenomena—Theory as to results obtained immediately the heat is first applied to the boiler.

It has already been explained that it is not uncommon to have an apparatus which, from the highest point in the flow pipe to the point where the return enters the boiler, measures, perhaps, only 4 feet vertical. The circulation of a large body of water then depends solely upon a difference in the weight of two short columns amounting to about 1 oz., without deducting any allowance whatever for friction or any trifling obstructions that may be present. In all horticultural works, where but a small rise and fall in the pipes is practicable, an obstacle must never be more than a trifle, or the results will be partially or wholly bad.

It not infrequently happens that with a view to convenience, or from necessity, a pipe, the return pipe probably, requires to be carried down below its normal course. Usually it is to pass a doorway, which it cannot do without being carried down to a level with, or below the floor line, as Fig. 68, and an instance might arise where a pipe has to be taken down below the level of the boiler itself. This is quite possible, even in glasshouse work, but it cannot be done so well as when an apparatus is carried up two or three floors of a building, with, as a matter of course, a greatly increased motive power.

The motive power of an apparatus is improved by increasing the vertical height of the flow and return pipes, as explained. Also by increasing the length of horizontal pipe, so that the water may lose more heat and create a greater difference in temperature (and weight) between the water leaving and entering the boiler. In horticultural work it has been pointed out that the former of these two methods can never be resorted to with a view to increase the motive power, as every inch of vertical pipe that can possibly be fitted is usually required to work an apparatus of an ordinary character in the usual way. In these works the house is usually placed upon the level of the ground, and some gardeners prefer having the floor of the house below the ground level. The pipes cannot be put much above the floor level, and the boiler cannot be fitted far below, as a very deep boiler pit is objectionable (and quite impracticable where water is found 2 or 3 feet below the surface of the ground), so that we may consider that an average height from the return pipe at boiler to the highest point of the flow pipe is about 5 feet, representing say 2 oz. as the motive power. This is certainly a very weak power to permit of carrying pipes in a way, or doing anything, contrary to what favours the circulation.

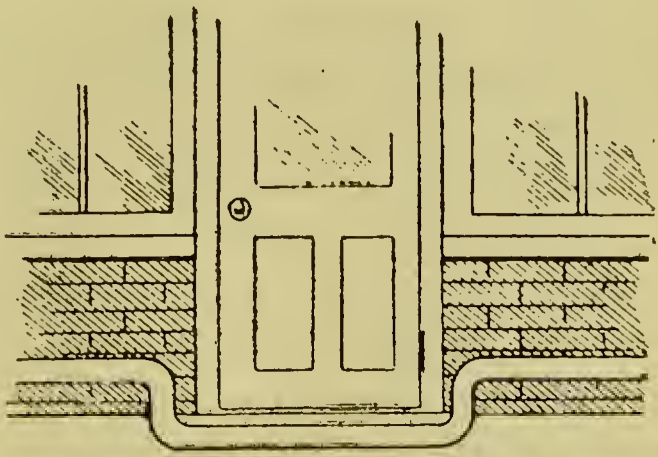
Fig 65.

The object in thus dwelling upon the weakness of the motive power that is obtained in this particular branch of hot-water works is to make it clear that precautions should always be taken to avoid peculiarities or irregular features in construction, particularly that of carrying pipes in a direction opposite to what is favourable to success, viz. a continually ascending flow pipe and a continually descending return pipe. The disadvantages of a low motive power are in reality two-fold, namely, the want of the power itself to increase the circulation, and the loss in velocity of circulation, which is clearly a drawback when obstacles have to be overcome. It takes much less to retard or overcome the motion of a sluggishly moving body (whether solid or liquid) than it does to interfere with anything travelling rapidly, or with a moderate impetus.

Before proceeding to discuss the possibility of "dipping" pipes in their course, it is desirable perhaps to just explain the question of velocity of circulation, as tending to make matters still more easily understood. No reliance, however, can be placed on the results arrived at, as though strictly correct in theory, they are greatly modified and varied in practice, particularly by friction,* quantity and size of pipe, &c.

Hood grasped the subject of velocity very strongly, as is evident by his treatment of it, as follows: "The velocity with which the water circulates in this kind of apparatus . . . can be calculated theoretically when certain data are agreed upon or are ascertained to exist. . . . This velocity is easily calculated; a gravitating body falls 16 feet in the first second of time of the descent, 64 feet in two seconds, and so on, the velocity increasing as the square of the time. . . . To estimate the velocity of motion of the water in a hot-water apparatus, the same rule will apply. If the average temperature be 170°, the difference between the temperature of the ascending and the descending columns 8°, and the height 10 feet, when similar weights of water are placed in the two columns of an inverted siphon, the hottest will stand ·331 of an inch higher than the other, and this will give a velocity equal to 79·2 feet per minute. If the height be 5 feet, the difference in temperature remaining as before, the velocity will be only 55·2 feet per minute; but if the difference in temperature in this last example had been double the amount stated—that is, had the difference of temperature been 16°, and the vertical height of the columns 5 feet, then the velocity of motion would have been 79·2 feet per minute, the same as in the first example, where the vertical height was 10 feet and the difference in temperature 8°. This therefore proves, in corroboration of what has been already stated, that reducing the temperature of the water which returns into the boiler, either by using smaller pipes (which part with the heat faster), or by increasing the length through which it flows, so that there may be more heat radiated, has the same effect on the circulation as increasing the vertical height, leaving out the question of friction.

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* The writer is always in doubt as to whether the term "friction" is correctly applied here. When we speak of this phenomenon we suppose that it exists between two substances more or less rough (for the finest polished surface shows a roughness under a powerful microscopic glass), this roughness offering a resistance which prevents one of the bodies readily slipping from the other when their surfaces are tilted more or less out of level. But there are no substances so rough on the surface that they do not readily part company if they are forcibly moved or tilted right over. This is not the case with water, for if we take a finely polished surface and pour water on it, it runs off as fast as poured on, with the exception of some of the liquid that lies close to the surface referred to, and this, however it may be tilted, still adheres, even if the object is turned upside down. Consequently there must be an attractive or adhesive force—the former, most likely, as we cannot suppose it is a single layer of water particles that remains fastened, so to speak, on the surface, but very many layers, as the particles of water are so exceedingly minute. This property is manifested almost the same whether the surface be very rough or very smooth. It is therefore just possible that the particles of water next the inner surface of the pipe are quite still, although the particles of water next them may be in motion, in the same way that in watching the circulatory movement of water heated in a glass jar, we find the top surface or "skin" of the water is perfectly still, as already explained.

"The velocity for 3 feet of vertical height by the same rule will be 43·2 feet per minute, for 2 feet of vertical height 36 feet per minute, and for 18 inches of vertical height it will be 30·7 feet per minute, if the difference between the two columns be in each case 8° the same as in the former examples. It must be here observed, however, that although it appears by these calculations that increasing the vertical height of the pipe fourfold will produce a double velocity of circulation, as the water will then pass through the pipe in half the time, the difference between the temperature of the flow pipe and of the return pipe will be lessened, so that the quadruple increase of height will only produce a rate of circulation about one and a half times the original velocity."

As Hood remarks, such is the result in theory (as regards the sums and figures stated). In practice we shall never meet with an instance agreeing with these results, even in an apparatus small in size and constructed upon the most correct principles. To get at the true velocity a large amount must be deducted from these theoretical figures, as the data given are arrived at upon the calculation that the substance is falling through air. Now air offers no resistance comparable to water passing through pipes, particularly those that are horizontal, in which the water is helpless to assist in its own movement. Then every angle offers additional resistance, not merely a resistance of friction, but a tendency to obstruct the whole mass bodily. With an ascending or descending pipe we more nearly approach the theoretical velocity, but in these pipes we only get a true velocity near the centre, the particles nearest the surface being more sluggish in movement.

Hood explains that the motions in a vertical flow pipe and a vertical return pipe differ in character by reason of the outer particles not clinging to the pipe surface in the latter pipe as they do in the former. The water in the return pipe he considers moves bodily, so to speak, instead of the centre particles moving faster than the particles near the surface, as they do in the flow pipe, as just explained. The writer has, it must be feared, to contradict this, as in many experiments with glass pipes this phenomenon has not been detected. It is obvious from Hood's explanation that the deduction has been arrived at by considering the water in the return pipe to be cold, which only happens when the fire is first started.

In dealing with an apparatus in which we wish to dip one or both pipes below their normal course—that is, to make the pipe descend to pass some obstacle and then rise up to its original level—we have to remember first, that it introduces an obstacle to the natural course of the circulation, and secondly, that in horticultural work the circulation at its best is hardly anything better than feeble. The cause of a dip proving a check to the circulation is as follows :—

We may suppose an apparatus constructed as at Fig. 69, an exceedingly simple one, as it is merely a pipe proceeding all round a greenhouse,* but in carrying the pipe along all four sides of the house we encounter a doorway under which the pipe must be carried at the floor-level as shown. Now from the top of the boiler to the point E everything is normal (as in fact it is to the point G) ; but in the vertical pipe E to F we have a descending column of water lighter than the ascending one in the pipe G to H, for, according to the principles laid down, the water gets colder and heavier as it gets nearer (in its return) to the boiler, due to loss of heat by radiation.

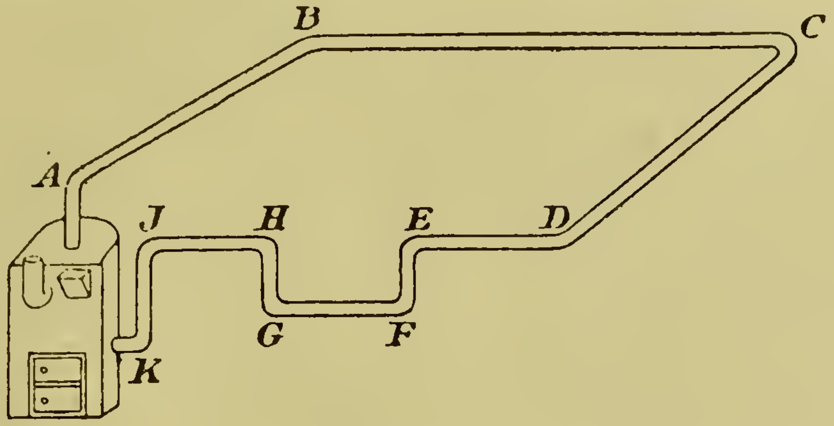

Fig. 69.

The fact of the water in the pipe G H being heavier than that in the pipe E F naturally tends towards a back or retrograde movement, it now being clearly understood that it is the fact of the water in one pipe being of greater weight than in the other (of the ordinary circulating services) that brings about the movement which is termed the circulation. The heavier forces the lighter bulk before it, and not the heavier giving way, retreating before the lighter, as we require it to do in this instance.

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* Let it be clearly understood that this is not the usual way of arranging the pipe or pipes. They are usually carried up and down two or three sides of the house so as to avoid the doorway, as explained in the last chapter. The above arrangement is merely adopted for the purpose of illustrating the "dipped" pipe.

In the simple dipping of a pipe under a doorway there is no very marked difference in the temperature of the descending and ascending pipes referred to, as they are so near together, although there would be sufficient difference to bring about a movement in the wrong direction if the general motive power of the apparatus did not exist. If a distance of say 20 or 30 feet separated the two points F and G, a greater obstacle would present itself, as the further the distance between these two points is, the greater must be the difference in the temperature, and consequently the weight of the water in the two pipes indicated. It may be accepted as a rule that the greater the space referred to, the greater the resistance offered to the circulation.

To admit of the dip being made, the motive power of the apparatus must be sufficient to overcome this inclination to return movement, and it must be sufficient also to have a surplus of power to produce the general circulation required. This residue of power should be sufficient, as a feeble movement will not only fail in conveying heated water to the extremity of the apparatus by reason of its slowness permitting the heat to radiate before it can get to its destination, but it will readily fail if an obstacle get in the pipe. A leaf (so frequently found in the pipes), or a collection of refuse, would totally stop the circulation. This requires consideration, as in most country places, pond, ditch or surface water is used to charge the apparatus.

To show a simple way of calculating if the dip in the last illustration is permissible, we can take another figure, Fig. 70, and by spacing it out in imaginary degrees of temperature as shown, tolerably correct results will be arrived at by comparing the mean temperature in the ascending and descending volumes of water. From A to B we have 179° mean, and from J to K we have 141° mean, a difference of 38°, and to this we can add, say, one degree for the portion of vertical return pipe at C, D, making 39° to produce the circulation if the dip was absent. If we take the mean temperatures of the two vertical columns of this dip we find there is a difference of 7°, this being 7° of resistance to the circulation, and which has to be deducted from the 38° last mentioned. This, it will be seen, however, leaves ample margin of motive power in this case; but, as already pointed out, if we increase the space between G and F, or increase the depth of the dip, further resistance is offered.* In Figs. 69 and 70 just explained, the dips are shown in that portion of the pipe that is returning to the boiler, whereas in Fig. 69 the flow pipe might have been carried towards the doorway, where the dip is situated, first. In this case no more nor less resistance would have been offered by the dip itself, supposing its dimensions to be the same in each case, but when first starting the circulation the obstacle (for the dip is an obstacle) would be encountered before the circulation gained the impetus it would do if the dip was situated as Fig. 70. We must give every consideration to what happens when the circulation is first started, as any ill effect that is to be experienced will give the greatest trouble at this time.

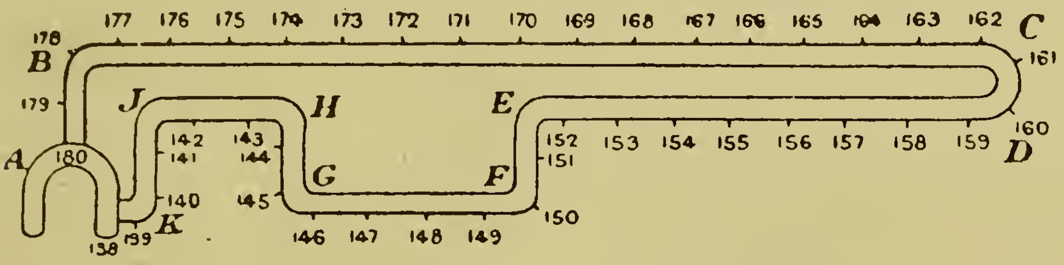

Fig. 70.

In Hood's description of this he shows the dip in the flow pipe as Fig. 71, his explanation dealing only with the resistance offered by the dip, irrespective of its situation, as follows:—

"In an apparatus constructed thus, the motion through the boiler and pipe A B, and through the descending pipe C D, takes place according to the principles described. But it is evident that, on motion commencing in the return pipe *y z*, in consequence of the greater pressure of C D than of A B, the water from A will be forced towards *e*, at the same time that the water in *e f g h* flows towards C. But when a very small quantity of hot water has passed from the pipe and boiler A B into the pipe *e f*, the column of water *g h* will be heavier than the column *e f*, and there will be a tendency for motion to take place along the upper pipe towards the boiler instead of from it. This force, whatever be its amount, must be in opposition to that which occurs in the lower or return pipe in consequence of the pressure of C D being greater than A B; and unless, therefore, the force of motion in the descending pipe C D be sufficient to overcome this tendency to a retrograde motion, and leave a residual force sufficient to produce direct motion, no circulation of the water can take place." If we could dispense with the ascending pipe G H (Fig. 69), and continue the return pipe straight from G to K, the circulation would be normal, which is of course the best course to aim at if possible, but this would be governed chiefly by the distance from G to K, and whether it would be desirable to carry this pipe along the floor-level.

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* It must be explained that in these calculations again, the results are but theoretical, as the temperature of the air, the size of the pipes, and the position of pipes, all tend to vary the general effect.

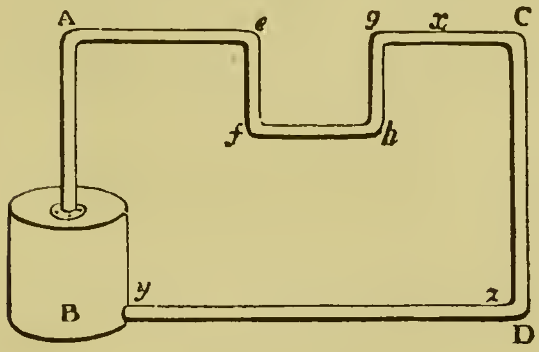

Fig. 71.

In all the illustrations referred to, the dip has not been shown as extending below the point where the return pipe enters the boiler, in fact, its depth would not need to exceed 24 inches at the utmost; but, paradoxical as it may seem, it is quite possible to extend the dip below the bottom of the boiler without creating any greater obstacle or resistance to the circulation than with the dips already explained.

Supposing a deep dip to be required at some point near the boiler (in which case the pipe would not be required to ascend to its original level again), the pipe could be arranged as Fig. 72, in which, by spacing out in imaginary degrees of temperature, we get a mean of 179° in the ascending pipes

A, B, and a mean of 149° in the descending pipe E to *, the difference being 30° in favour of the circulation without the dip; the resistance offered by the dip is 6°, leaving a sufficient margin for effective work, to which may be added the effect of the small piece of descending pipe C to D.

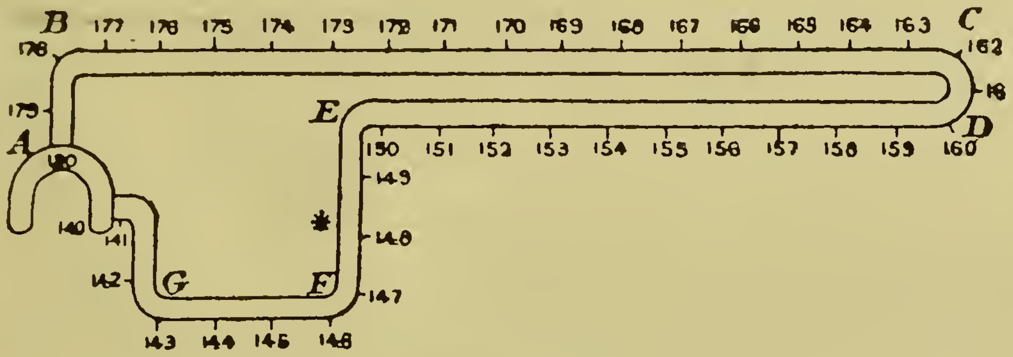

Fig. 72.

In this instance it will be seen that the apparatus is normal from the top of the boiler at A to the point in the descending pipe marked *, which is opposite the point where the return enters the boiler. It is almost the same (so far as the resistance offered by the dip is concerned) as placing the dip as Fig. 73, therefore if this dip is of the same dimensions

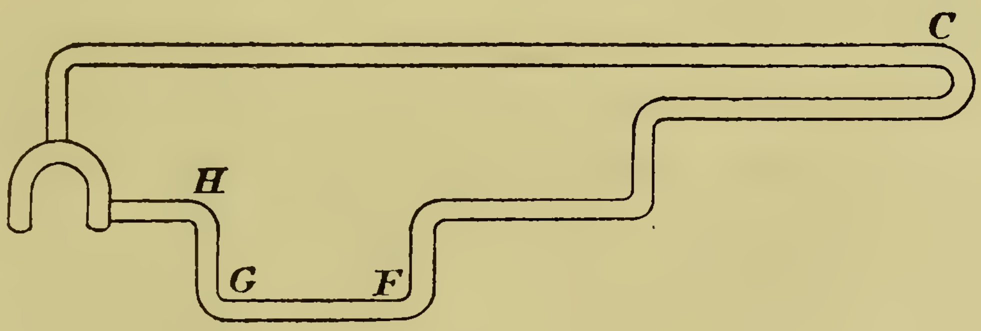

Fig. 73.

as the one described in Figs. 69 and 70 it will only offer the resistance to the circulation that these latter would do, even though in one case the dip extends below the bottom of the boiler and in the other the dip does not reach this point. In this case, as in the others, the resistance is increased by increasing the space between F and G, and also, of course, by increasing the depth of the dip.

In describing the results obtained from an ill-formed apparatus, Hood points out that occasionally an apparatus can be met with which, although apparently constructed on the worst principles, has, in consequence of various circumstances, been favourable in results; and he goes on to describe an apparatus constructed as Fig. 74, where the pipes were not more than 3 inches apart, "yet the water circulated with freedom, but in this case not only was the pipe of considerable length, and without any angles or turns, but the size of the pipe was only 2 inches diameter, so that the pipes cooled twice as fast as they would have done had pipes of 4 inches diameter been used."

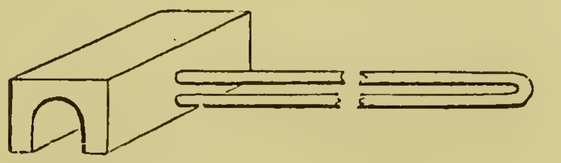

Fig. 74.

It can hardly be supposed (although the intention seems very clear) that Hood intended this last-described apparatus to be an instance of "construction on the very worst principles," as there are hundreds if not thousands of small works carried out in precisely this manner. Providing all other points in the apparatus are correct, the distance between the two pipes is sufficient to ensure success, if the apparatus is small in size. There is a very common practice (which, however, cannot be recommended for reasons to be presently stated) of heating a small greenhouse or conservatory from a kitchen range boiler. If the floor of the greenhouse is on a level with the kitchen floor, or a little below it, as is often the case, the pipes will most usually be found taken from the side of the boiler, which will not always permit of their being more than 3 inches apart, yet so far as the circulation is concerned all goes well, so much so that a complaint is rarely heard of its working badly.

If an apparatus was constructed as Fig. 75, with the pipes as exactly level as possible to get them, a circulation would be found to set up in the pipes and without any hesitation at the start, although it cannot be relied upon to circulate in the same way every time it is started afresh. In a series of experiments made with this apparatus, it was found sometimes that, what hitherto answered as the flow pipe, acted as a return, and *vice versâ*, although there seemed to be a preference for one pipe to act as an established flow pipe and the other as a return.

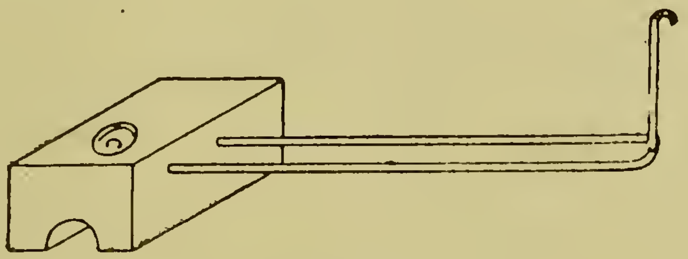

Fig. 75.

If we carefully investigate the question of how the circulation first starts or sets up, we shall see that it is quite natural for it to act and traverse the pipes (circulate) that are connected on a level with each other as just described. Whether inquiring upon a theoretical basis or from results obtained from practical experiments, we shall find that instead of the water failing to circulate (when the apparatus is constructed contrary to accepted notions) the difficulty will be to get the water to remain still—an apparatus has to be erected in an extraordinary manner to prevent the water moving in the pipes.

Returning to the apparatus with the pipes starting level (Fig. 75), in accounting for the results we must consider what happens when heat is first applied, the water in all parts of the apparatus being stationary up to that moment. Movement may be considered to first take place in the water nearest to the source of heat, which we will suppose is at the bottom. Almost at the very instant the particles are noticed to move there they will be found moving in the other parts of the boiler also. The movement everywhere is almost simultaneous, for it can be so readily seen that the movement of water at the bottom of the boiler is due to and dependent upon the pressure and consequent movement of the water at the top.

The instant the water in the boiler becomes warmed and rarefied and is in movement, we should have the phenomenon of hot water being in the boiler and cold water in the pipes extending from the top of the boiler. In other words—rightly considering the pipes as an extension of the boiler itself—we should have hot water in the general body of the boiler, while a portion of the upper part is tenanted by cold water. This, needless to add, is against all accepted principles, and cannot exist unless the proportion of cold water referred to was confined in some way, and even then it would set up a circulation of its own, if the hot water imparted heat to it. We thus see that the cold and heavier water cannot remain in these pipes at or near the top of the boiler if they have free communication with the heated water which is practically beneath them, but it is equally obvious that the cold water cannot come down both pipes at the same time; one must act as a flow pipe and the other as a return, and this they readily do. The only inference to be arrived at for their acting as flow and return is that they may not be perfectly level, or some inequality or trifling obstruction in one pipe permits the other to take the lead.

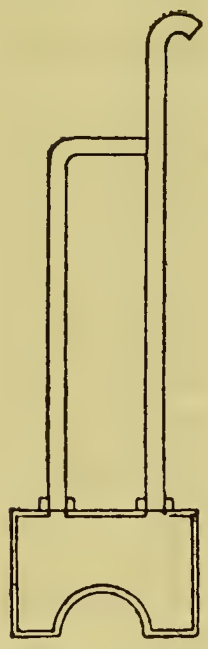
Fig. 76.

We have practically the same result when we connect vertical pipes both on top of a boiler (without continuing one of them down inside), as Fig. 76, only that the explanation just given bears even a stronger application in this case. The water within the pipes of this arrangement is truly on top of the water in the boiler, and it certainly will not remain there when the latter becomes heated ever so little, and a circulation will be found to set up directly heat is applied to the boiler. It is a common impression, particularly amongst workmen, that this last arrangement described would fail to act by the water remaining stationary in the pipes, although the water would become of a high temperature in the boiler; but this is incorrect, for the water will never fail to circulate up one pipe or the other.

It is most peculiar to note that when the pipes start level, no reliance can be felt as to which pipe will act as a flow and which as the return. Sometimes the water will proceed up one pipe when the apparatus is first started, and when the circulation is once established it will continue acting in the same way. If it is allowed to cool down and the water to become stationary, then it is just possible the water will flow up the other pipe when started again.

It must not be supposed for one moment that in dealing with the circulation that takes place when pipes are started from level points, it is intended to recommend this method. The question has been dealt with to dispose of, or put upon a more sound basis, one of the many problems that are always presenting themselves in this work. The customary plan of having the flow pipe 9 inches or more above the return pipe—that is, the flow pipe at the extreme highest point in the boiler and the return at as low a point as possible—is decidedly the best arrangement. It is reliable, for the water will always circulate one way, and it in every way aids natural results.

Hood has set it down that 12 inches should be the recognised minimum distance between the two pipes: this is a safe and practical suggestion. It is somewhat unusual if this space cannot be had, as boilers made for heating purposes are seldom less than, say, 15 inches high. The illustrations given in other chapters show the correct points for the two pipes, but of course the return can come in at either or both sides, and it is not necessary by any means for the flow or return to be situated centrally from front to back, as will be seen in the illustrations referred to.

CHAPTER VI.

IRREGULAR FEATURES—continued.

Other and more irregular forms of apparatus—Methods of calculating the resistance experienced—A phenomenon opposed to a theoretical basis—Method of assisting the circulation in an irregular form of apparatus—Hood's suggestion to this end and its advantages and disadvantages—Another and practical method of effecting a good circulation below the boiler level—The tank system—Further information as to expelling air.

A WELL-KNOWN and talented author upon "Heat" * clearly explains (theoretically) to what extent a pipe may be dipped, as shown in Figs. 77 and 78. In the first figure we have an apparatus which would undoubtedly extend up one or two floors of a building (thus differing from the horticultural form of apparatus, which has been almost exclusively treated up to this point). Its construction is normal, and shows a mean temperature of 160° in the ascending column and 117° in the descending column, a difference of 43 degrees to furnish the motive power, which, it is needless to add, would create a very rapid circulation in an apparatus wholly of vertical pipe. In Fig. 78 the mean temperature in the ascending column is about 135°, and in the descending column 135° also, so that, theoretically, there should be no circulation at all. Or, it can be varied by placing the boiler a little lower than shown in Fig. 78, as at Fig. 79 for instance, and the mean temperatures in ascending and descending columns would be, say, 134° and 128° respectively, a difference of 6°, which would produce a moderate circulation. According to the principles laid down this latter would be sufficient to do fairly effective work in a vertical apparatus, and shows conclusively that the higher we carry the ascending column the greater the motive power obtained. This, consequently, permits the return pipe being carried to a greater distance below the boiler than when the ascending column is of limited height, as occurs in horticultural works.

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* Box upon 'Heat'; London: E. and F. N. Spon.

As before mentioned, this is strictly correct in theory, but if any one erects a model apparatus as at Fig. 80, in which the pipe descends below the boiler, say three times as much as it rises above it, upon heat being applied to the boiler a circulation will almost immediately set in—that is to say, as soon after the application of heat as in an apparatus of normal construction. And the circulation will be in the correct direction, viz. ascending up the short pipe at the top of the boiler and returning by the pipe that enters the boiler near the bottom.

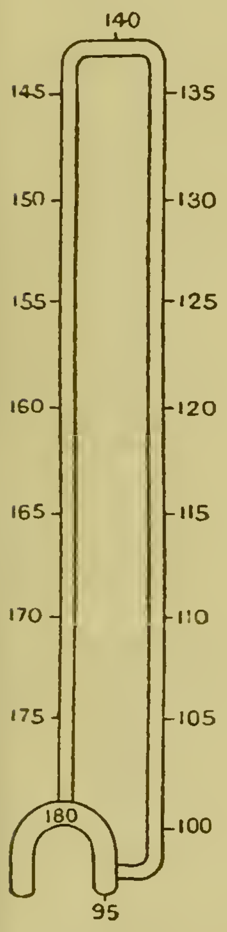

Fig. 77.

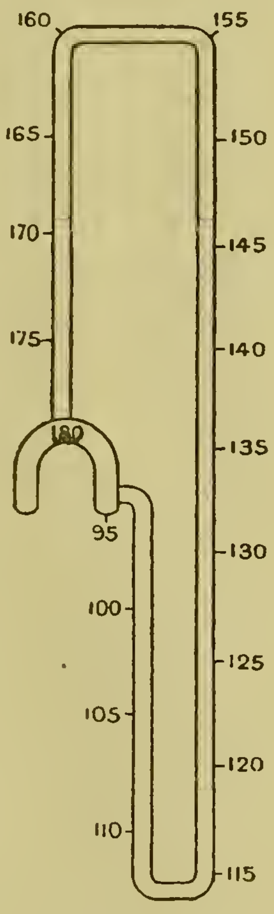

Fig. 78.

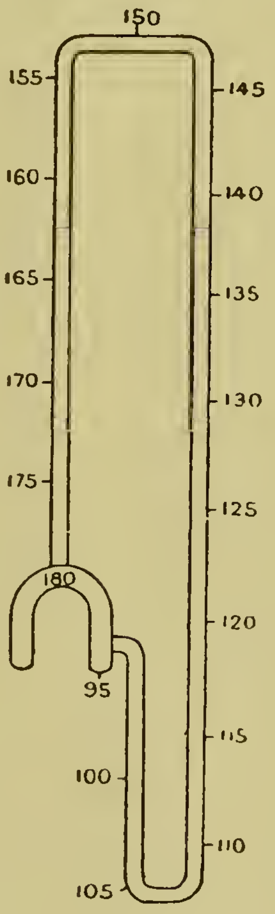

Fig. 79.

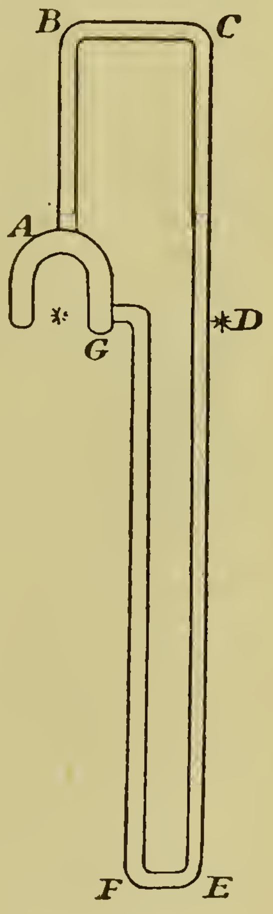

Fig. 80.

Although we may only make this experiment in a small model apparatus, yet the results in this case can be quite relied upon as being natural, although a little thought will show that it is opposed to all accepted principles.*

It is easy to account for the circulation or movement that first occurs in this case, as we may consider the whole of the apparatus above the two points marked * to be of a normal character, and the part below these points simply consists of an inverted siphon with an equal weight of water (while cold) in each leg. When heat is applied to the boiler we must, as a matter of course, quickly have the water in the column A B lighter than in the column C D, which will be sufficient to produce a movement in the direction of B to C, for while the water in the pipes below the points marked * remains cold (that is to say, not yet affected by the heat) it will have no effect whatever upon the circulation, no more than to move in whichever direction the difference in pressure in the pipes above may cause it. This may account for a circulation setting in when the heat is first applied, and up to the time that the heated water has travelled round to D. But when in the course of circulation the heated water reaches the point E or F (but not yet past F) then we shall have the column B to F heavier than C to E, yet the circulation continues (but more sluggishly) in the direction in which it started, and does not cease to do so as long as heat is applied to the boiler.

This experiment, although demonstrating a peculiarity in hot-water circulation as regards the principles and theories we recognise at present, is not valuable, for although the circulation remains constant, it is of so low a speed as to be useless for large works. But supposing such an apparatus was needed, then its efficiency could be rendered secure by applying heat to it at F, or at a low point in the pipe between F and G—not an additional boiler, but by passing a piece of the pipe through a small fire (which, however, would require to be kept alight all the time the apparatus was at work). Or a moderate-sized "Bunsen" gas burner would do, and be perhaps, easier of application, and certainly very regular in results. This, it must be quite understood, is supposing that the boiler cannot anyhow be placed at the lowest point, as it should be if possible.

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* A few years ago there was an apparatus exhibited at the Crystal Palace which had the flow pipe carried from the side of the boiler, descending to heat some coils below it, and then returning into the bottom of the boiler, *no part of the pipe services being as high as the top of the boiler.*

Hood describes a method whereby the introduction of some extra pipe or radiating surface, which he shows in the form of a coil, is the medium by which the pipes can be carried below the boiler to a greater extent than can be done if this coil was absent, and without impairing the circulation. His description is as follows:—

"In an arrangement of pipes, such as Fig. 81, the circulation will depend entirely upon the quantity of heat given off by the coil *c*, for it is evident that when the boiler B and pipe *a* are heated, the direct motion will arise in consequence of the greater weight of the water in the coil *c* and pipe *d* above that which is in the boiler and pipe B *a*. But as the water in the pipe *e*, below the dotted line, will be lighter than that in the pipe *f*, the tendency in that part of the apparatus will be towards a retrograde motion.

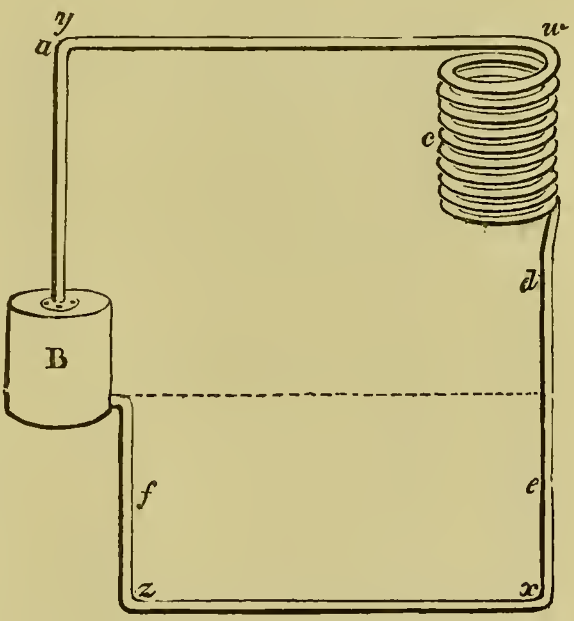

Fig. 81.

"The result of these two forces will be that if the water in the whole length of pipe *w x* is heavier than that of the whole length *y z*, in a sufficient degree to overcome the increased friction, circulation of the water will take place, and the velocity of motion will depend upon the amount of this difference in weight."

Nothing could be more sound than the principle here laid down—viz. that by putting a coil at the point shown we are able to dissipate more heat and make the water heavier by the time it exerts its influence in the descending pipe, and by this means it is rendered of greater power in overcoming the obstacle of the ascending pipe *f*, which is understood to be full of the heaviest water. But we could obtain the same result without the coil if we subject the pipe at the point *w* to some cooling influence, such as passing it through a small tank of cold water, or exposing just this point to the outer air. It brings most forcibly to notice, however, that in the majority of cases the mere fact of cooling the return pipe is, of all things, what should be avoided, as we must suppose that the object in carrying the pipe down below the boiler is for the purpose of providing heat (by a coil or series of pipes) at some point between *x* and *z*, in which case the object would be completely frustrated by the cooling influence at *w*. Therefore, although the principle is sound, it is not practicable, as a dip of such depth would never be necessary unless for some useful heating purpose, and in that case very little heat would be obtained.

Supposing such a dip was required, but not for any heating purpose, then the coil would be permissible, but perhaps it would be more useful to extend the pipe at the point *w* (as Fig. 82), and so make some good use of it instead of coiling it up, as the result would be practically the same.

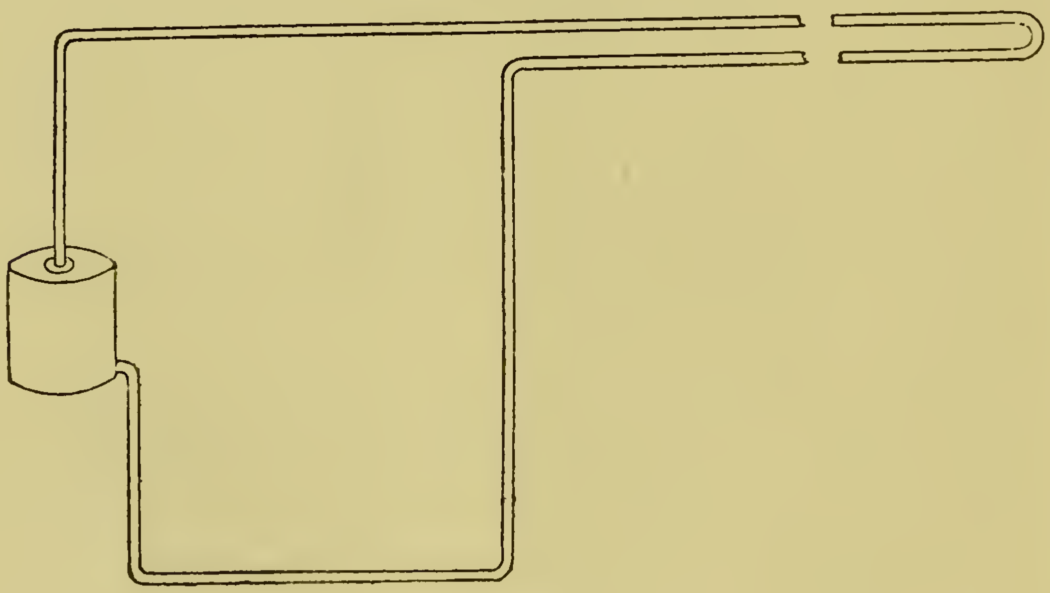

Fig. 82.

Hood also describes another method having the same principle and effect and the same drawback as the last, but instead of using a coil as the medium for cooling the water and rendering it heavier, he shows an apparatus, as Fig. 83, in which the flow pipe is carried by the nearest and most direct route to an open feed cistern or tank, and from there it is carried to wherever the heat is needed. He indicates a preference for this, owing to the absence of the friction which a coil would entail, and which is somewhat considerable.

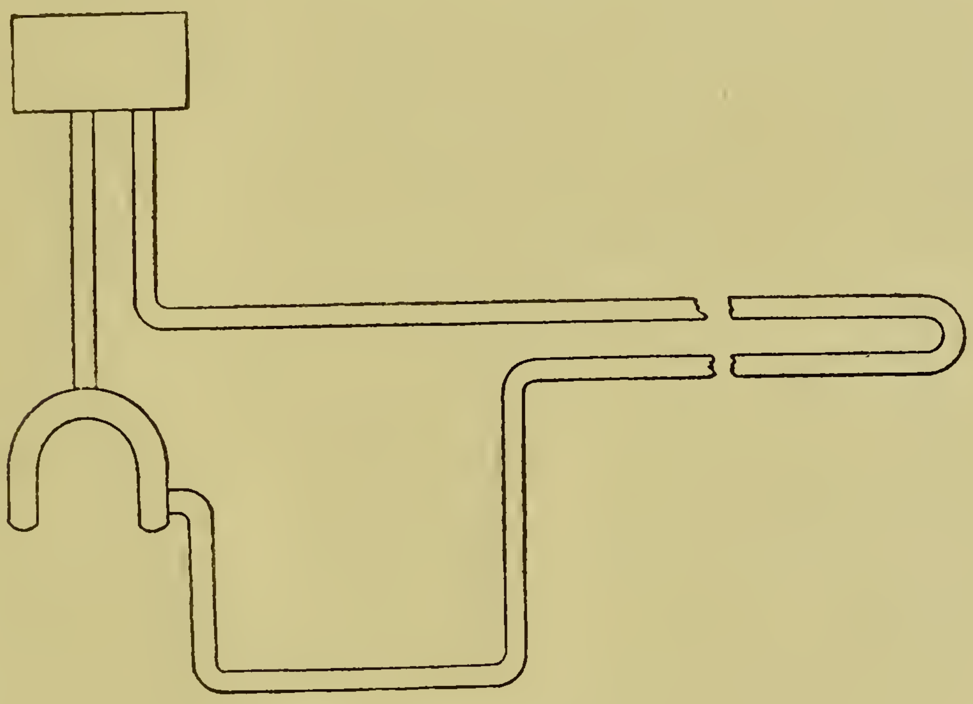

Fig. 83.

It will be plainly seen that if this system is going to be used as a means of cooling the water somewhat, that its use will be prejudicial to the object for which the apparatus is intended, and on this account it could not be recommended. But if the cistern is kept with a cover upon it, and in a fairly warm position, this method has many things in its favour, and it is not at all uncommon to meet with an apparatus so constructed and doing good service.

In the first place, it is understood that the cistern acts as a supply or filling cistern, and it possesses the advantages of allowing the freest possible escape of air, also of steam should the boiler become overheated. It prevents in a great measure, and in some instances entirely, the passage of air into the return pipe or pipes. It will be readily seen that air, however small the quantity, must take up some space and consequently will render the contents of the pipe or pipes lighter than if air was absent and the whole space occupied by water. When this arrangement is adopted it can be made to bring about a saving in stop valves or cocks, for, supposing it can be conveniently carried out, there need only be one flow pipe of a sufficient size from the boiler to the tank, but from the tank there may proceed two or even three or four return pipes to the boiler, the number being governed by the different directions in which the pipe requires to be taken. Then, whenever one or more of these services requires to be stopped, it is only necessary to insert a wooden plug into the pipe where it appears inside the tank, and this plug will of course prevent all flow of water through the pipe in question. One of the chief reasons, however, for the adoption of a tank (into which the water is circulated) is, that by fixing the tank in a high position, as near the roof of the glasshouse as possible, a higher motive power is obtained, and by this means we can with greater facility circulate below the level of the boiler. It has already been explained that one of the means of increasing the motive power is to increase the vertical height, and the greater the vertical height the greater the extent to which we can dip below the boiler.

An instance where this arrangement becomes desirable is when there are two or more greenhouses to be heated from one boiler, these houses being upon irregular ground so that they stand at different levels, and it is found impossible to have the boiler at the lowest end as usual. In this case it becomes possible that one set of pipes has to be carried a little below the boiler as Fig. 84, and in this case a tank becomes a necessity, for we should get poor results by running a pipe directly from the top of the boiler down to a point below its level, then up again on its return.

The illustration shows the tank fixed, this tank, however, being closed and having a steam or air pipe from it; this certainly does away with the means of plugging the pipes, but it is the best arrangement to save the heat and prevent a too lavish distribution of vapour.

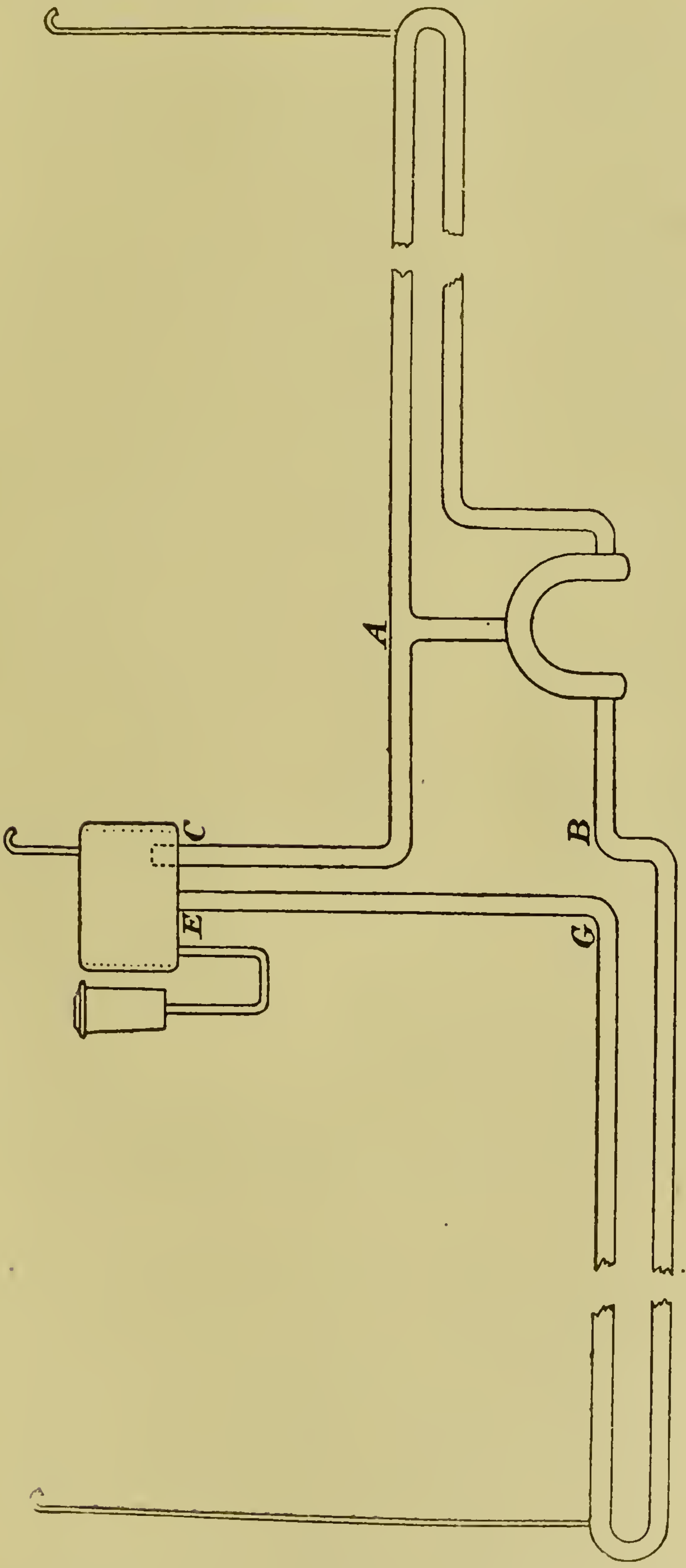

Fig. 84.

Example of horticultural hot-water apparatus with tank at the highest possible point to increase motive power of circulation. The purpose in this instance is to admit of the service, commencing at G, being carried below the level of the boiler. See p. 123 as to details of air vents, &c.

It must not be overlooked that in all these unusual forms of apparatus air cocks or pipes play a more important part than ever. It will be found that a good deal of judgment is required to successfully rid the pipes of air in a thorough manner. It is, however, a very necessary requirement, for in departing from normal arrangements we must in a greater or less degree impair and lessen the motive power, and but a trifling accumulation of air under these circumstances may ruin efficiency altogether.

In Fig. 68, p. 99, an air vent would have to be placed at the highest point of that portion of the pipe on the right-hand side of the door, and also at the highest point of the pipe on the left side, as a dip like this is a certain obstacle to the passage of air either way, whether it be the flow pipe or the return. It may be pointed out that in this arrangement the depth of the dip can be reduced by using a special form of pipe that is made to pass under doorways. This pipe has a flat even top, so that it need not be covered with earth or the paving material, but be fixed level with the floor line.

In Fig. 69, p. 103, we may suppose the pipe ascends slightly all the way from A to C, this latter letter being at the highest point, where an air vent would be required. From this point C the pipe descends to F, and no further outlet would be required thus far. At H (which we may suppose is a trifle higher than J) another vent would be needed, as any air collected in this short piece of horizontal pipe would not be able to escape either way (it descending at both ends), neither could this pipe (J to H) properly fill when charging, unless an air vent be there.

In Fig. 70, p. 105, an air vent would be needed at C, and one also at H (supposing H to be a trifle higher than J) in exactly the same way as the last described.

In Fig. 71, p. 106, we have practically the same apparatus again, although the dip is situated differently; at *e* an air vent would be needed, as we may suppose this point is a trifle higher than A, and again at C provision would have to be made for air exit. At no other point in the apparatus would it be needed, provided the apparatus is erected in the usual way, which would make C the highest point, all pipes rising to, or descending from it.

In Fig. 72, p. 107, again, the point C should have its air vent, and this in a small apparatus would be sufficient, but if where the return enters the boiler there is ever so short a length of pipe, it would be desirable to put an air vent in it at its highest point of course. A short length of flow or return pipe may sometimes be fixed in a manner that appears to be perfectly horizontal, and a difficulty would be experienced in deciding where to put the air vent, but this can be immediately settled by using a spirit-level. Nothing could be more reliable than this instrument, as its chief feature is a pipe having water with a globule of air imprisoned in it. The direction which the air takes in the spirit-level will be exactly the direction the air will take in the hot-water pipe, supposing the level to be resting evenly upon the pipe in question.

In Fig. 73, p. 107, again, C is the necessary point for an air vent, and also H if we suppose H to be a trifle higher than the point where the pipe enters the boiler. The two pieces of horizontal pipe on the opposite side of the dip to H do not require any provision for air exit, as these should both ascend towards the point C, i.e. descend toward the boiler.

In Figs. 74, p. 108, and 75, p. 109, an air vent would be needed at the termination of the pipes furthest from the boiler (as shown in Fig. 75), but if an apparatus was constructed in this manner the boiler itself would also require an air vent of some sort at the top, unless the upper pipe started quite flush.

In Fig. 83 we touch upon debatable ground when suggesting a position for the air vents. One of course would need to be at the tank, unless it had an open top or loose lid, but with the circulating pipe it must depend upon how it is run. With this plan of apparatus there are as many advocates for making the upper pipe descend towards the end, the under pipe being carried horizontally as Fig. 85, as there are advocates for making these two pipes ascend towards the end in the usual way as Fig. 86. With Fig. 85 an air vent should be provided where shown, to prevent a possible air-lock when re-charging, and to aid when first charging; and in Fig. 86 the air vent would require to be placed at the extremity as shown.

There is every argument in favour of carrying the pipes, under this particular tank system, in the manner shown at

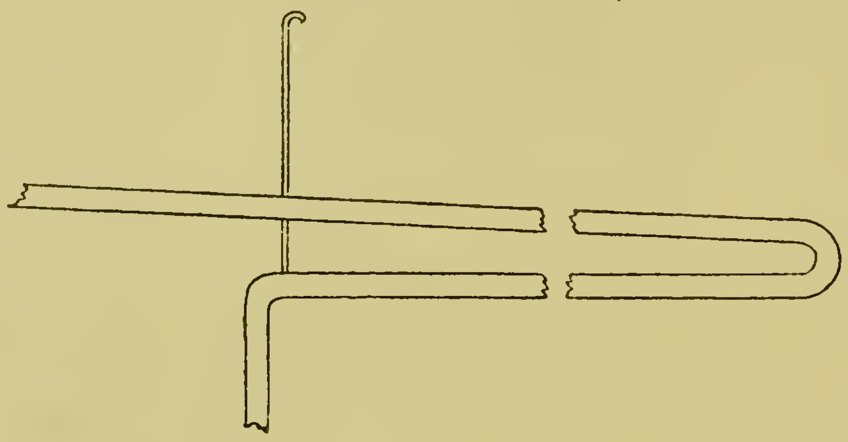

Fig. 85.

Fig. 85, thus treating the pipe from the tank to the boiler wholly as a "return." A better plan still, where possible, is to let the return pipe from tank to boiler take a descending course all the way, as Fig. 87. In this illustration the fall of the pipe is shown much greater than it need be, but this is

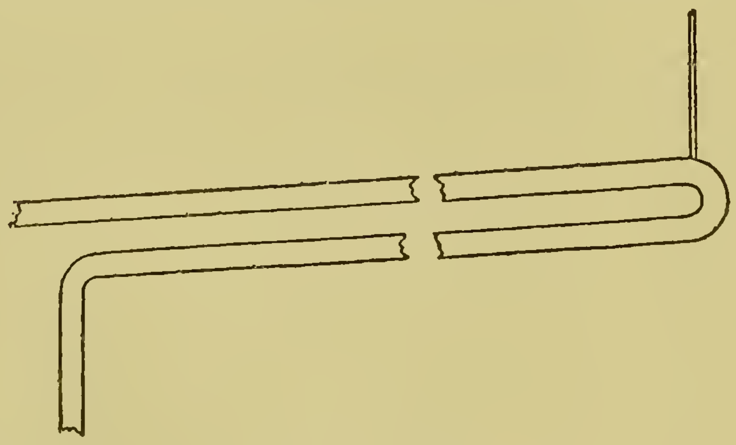

Fig. 86.

done to make the meaning clear. No air pipe whatever would be needed with this, neither is there any pocket or place for water to remain in when the apparatus is emptied. This latter is a prolific source of trouble, for, on re-charging, the pocketed water will often prevent air being driven out of the apparatus as the new water flows in. It will thus bring about air-lockage, the same as explained on p. 56. This method of running the pipes cannot, as a rule, be conveniently used for a main service which has branches from it.

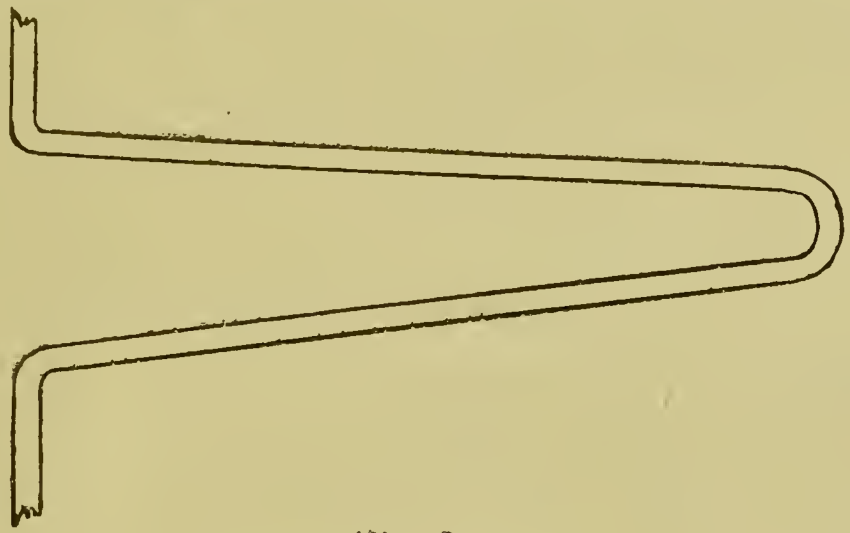

Fig. 87.

In Fig. 84, p. 119, there are introduced two quite distinct systems, but which work in complete harmony (with a little care), and the results obtained by both arrangements should be satisfactory in every way. The whole of the apparatus on the right-hand side of the point marked A is of the ordinary simple description, and an air vent at the extremity as shown will suffice for this portion. An air vent is also needed in the tank unless it has an open top or loose cover, but this is governed by the use to which the house is put. As an instance, it will not do to have an open top in a grape house, where an excess of moisture is usually objectionable. With the pipes on the left side of A, an air vent can be fixed as shown if these pipes rise towards that extremity; but as just described, it is better to arrange them as Figs. 85 or 87, and in each case an air pipe should be fixed at B. This air pipe might not be much needed at first charging, but in this case it must be borne in mind that, unless special provision is made, the lower pipe will not be emptied when the apparatus is discharged for any purpose, and this would cause a trap to be formed for air when re-charging. The tank in this system should be from 10 to 25 gallons capacity, according to the magnitude of the job, but the water supply must not be arranged for the tank to fill more than about a third or half full when cold, as already explained under cold water supply. The upper termination of the flow pipe need not stand up more than 3 inches inside the tank, and the pipes A to C and E to G need not be larger than 2 inch, if the apparatus is limited to heating one house on each side of the boiler as shown.

If any part of the pipes just named are carried out in cold situations (underground or outside the house), it is very necessary indeed to cover them with some poor heat-conducting material, to prevent loss of heat, as will be explained fully. It would also be necessary in this apparatus to provide throttle valves to each set of pipes, as it may be taken for granted that the portion of the apparatus on the right of A will have the freest circulation, and will take the "lead," as it is termed, and it will be found that if the circulation starts in one direction more strongly than another it will continue so, and the part of the apparatus that is working the least effectively will fail to pick up and recover itself, in fact it may seem to get worse. This, however, is exceedingly easy of remedy by the use of valves, the gardener regulating them as necessary or according to his desire. Even in an apparatus constructed upon simple principles, if it has two or three distinct branches, the gardener usually finds some regulation necessary, and, strange to say, the regulation varies considerably in the same apparatus, one branch sometimes working freely at one time and sluggishly at another.

The water supply (still referring to Fig. 84) is arranged for by the erection of a small filling cistern at the side of the tank. This, however, is not so necessary if the tank may have a loose cover or open top. The filling would then be done by hand from a can, or by a ball valve if a regular service of water is accessible. In filling by hand there is an objection in the fact of the tank being situated up out of reach, and it is not easy to tell when the supply wants replenishing unless an indicator is fitted. The usual indicator is a float inside the tank, a pulley on the top edge, and a piece of wood to drop down outside. This piece of wood or indicator is connected with the float by a light chain or cord which passes over the pulley as Fig. 88.

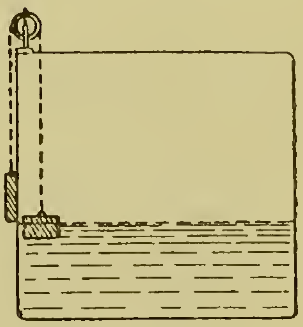

Fig. 88.

It will be noticed that there is a dip in the pipe that connects the small cistern with the tank, the object of this dip being to prevent the contents of the small cistern becoming hot, which would be of no advantage whatever. It has been explained that water (when warmed) will circulate with considerable freedom in a single pipe from a boiler. In the instance just referred to, we may consider the tank as acting the part of a boiler, and a circulation would set in between the tank and the small cistern if the connecting pipe was straight, i.e. not dipped. The circulation would certainly be sluggish, but nevertheless sufficient to make the water in the small cistern hot, which would be an objection that the small cistern is provided expressly to obviate. The feeble circulation that sets up in a single horizontal pipe is immediately checked when the pipe commences to descend. This dip should be about 6 inches deep. A small plug could be fitted in the lowest point of this dip if there was any liability of stoppage by dirt, &c.

CHAPTER VII.

CAUSES AFFECTING THE CIRCULATION.

Friction—Table of relative degrees of friction in different sized pipes—Different purposes for different sized pipes—Limit to circulation—As to limiting the length of services—Obstructions and faults—Erratic results and their causes—The effect of air in circulating pipes—Reversed circulations—As to whether the flow or the return services should contain the greatest amount of water.

THE subject of friction has an important sound, and in theory it ranks as a moderately important subject, but it is doubtful whether the question has more than the scantiest attention from the hot-water engineer. No one can aim at more than constructing the apparatus on as simple a plan as possible, and in neither using too small a pipe,* or introducing elbows where bends should be used. Many of the English wrought-iron fittings, especially tees, make very abrupt angles ; these are referred to in the chapter on Fittings.

Hood gives a table of the relative degrees of friction, or resistance by friction, that arise in pipes of various sizes. This table is sufficiently accurate for all practical purposes, although not strictly correct as to fractions of quantities which, however, are really not needed for this purpose. The results were arrived at by emptying the contents of a given sized vessel, from a given height, through various sized pipes.

Diameter of pipes	½	1	2	3	4 inches
Friction	8	4	2	1·3	1

From this it will be seen that the smaller the pipe the greater the resistance opposed to the motive power, and although it has been shown that the motive power (other circumstances being favourable) is increased by using small pipes (which lose their heat faster and so create a greater difference of temperature between the outflow and inflow at the boiler), yet by aiding the circulation in this way we introduce another objectionable feature, which may be said to about equalise and make the movement only the same as in a larger pipe.

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* See chapter on sizes of main and branch services.

In horticultural works 4-inch pipe is nearly always used, the only exceptions being in cases where the apparatus is very small, or where the gardener has some special idea of his own, for, as already stated, the gardener usually has considerable authority in this matter. In these works where so little vertical and so much horizontal pipe appears, friction would play an important part if small pipes were the rule. The large pipe, however, in addition to obviating this difficulty has the advantage (important in glasshouses) of giving a more regular temperature. The comparatively large quantity of water that a 4-inch pipe holds does not show fluctuations of temperature at the fire nearly so soon as a smaller pipe would, and this, very correctly, is of the utmost importance in the average gardener's or professional grower's opinion.

For churches, chapels, and halls, or any places where the apparatus is not working continuously, smaller pipes are frequently used, as it is desired to heat the building up as quickly as possible after the fire is lighted. One 4-inch pipe with its approximate circumference of 12 inches holds about as much water as four 2-inch pipes with an approximate total circumference of 24 inches, so that for rapid results the advantage is with the latter, which has so much more radiating surface for a given quantity of hot-water furnished by the boiler. On the other hand, of course, the smaller pipe cools more quickly if the fire slackens, but this is not objectionable in the places named, but it would be in horticultural buildings. The fact that from a fluctuating fire large pipes give a more even temperature than small ones, is the chief feature in their favour in glasshouse work, but at the same time nothing is gained by having larger pipes than the 4-inch size.

If it were not for friction it is reasonable to suppose that we might obtain a circulation for an unlimited distance; but under present circumstances this would be no advantage. The longest distance in a horizontal direction that the writer ever saw an apparatus carried was 250 feet, extending from the extreme east to the west wing of a nobleman's residence. This, which was upon the high pressure system, worked excellently, and it is doubtful if a system of pipes ever has to extend a greater distance, in a horizontal direction, than this. When the day arrives that hot water will be laid on to our houses from street mains, its presence throughout an extensive area would not depend on any circulating system. It would be pumped there. A circulation of the heated water would most probably be necessary, but the movement would be brought about by mechanical aid and not by convection. In more than one of the gigantic apartment houses in America the heating, done by hot-water radiators, relies on a pump keeping up the necessary circulation. This arrangement admits of the pipes being run in any convenient direction without specially considering the rise and fall.

In the same way we might consider that the increase of vertical height in an apparatus would increase the motive power proportionately to an indefinite extent, but in this case the friction would eventually reduce it to a mean rate. Fortunately this need give us no anxiety, as the highest buildings we have at present are not high enough to bring about any objectionable results in this respect.

When an extensive apparatus (extensive horizontally) has to be erected, it is best where possible to arrange for two or more distinct services to be carried in different directions in preference to one continuous run of mains extending hither and thither all around a building. This would be effected by placing the boiler somewhat centrally to the work to be done, or in some instances by a main flow and return to a central point and thence branching off in different directions. This will not reduce the friction in aggregate, as we may suppose, that about an equal quantity of pipe is used in each case, but in using the long single service the friction reduces the flow of water to the extent that by the time it is nearing its return to the boiler it will have lost all its heat and be worthless for any purpose near this point. In other words, two or more short services, which do not permit of the loss of a great amount of their heat by the time they return into the boiler, are preferable to one unusually long service in which a greater portion of the return pipe contains water at too cool a temperature by reason of the comparatively long time that has elapsed since it left the boiler.

It will be understood that the length of horizontal pipe could be effectively increased by increasing the height of the vertical portion, as by the latter means we increase both the motive power and velocity. By thus increasing the speed of circulation we proportionately overcome the trouble referred to, as the quicker the water is in getting back into the boiler the less heat it will lose in its passage. This result is important in glasshouse work as the return pipe is intended to distribute heat as well as the flow. With a circulation of moderate length the whole of the return pipe will be usefully distributing heat, and the heat will be more equally distributed everywhere. The plan of increasing the vertical height cannot, however, well be adopted in horticultural works, as will be understood.

In suggesting that preference should be given to two or more services in place of one very long one, it must not be thought that an eighty or hundred foot run is too long by any means. Where there are three or four glasshouses all in a line it is quite the usual and proper thing to heat them from a straight line of main pipes coming from a boiler situated at one end, and in building works there may be mains in the basement fully this length. It is intended to suggest that when opportunity occurs it is best to take separate services in different directions from a central point rather than one main service from the boiler around a wide area.

As already explained several times, the power which brings about the circulation in horticultural works of an ordinary character is, at the best, feeble. On this account every care should be taken in carrying out the work after it is planned; for, granting its arrangement to be good, it is just possible a small fault introduced will have a disastrous effect. The most common cause of this in new work is the introduction by inadvertence of some foreign material into the pipe. Some men leave the ends of unfinished services open when they leave their work, and something may chance to get in; or, in the reverse case, when men temporarily plug the unfinished end with a cloth or some such material, instances have been known where it has been accidentally pushed in and lost sight of.

It may not seem necessary thus to dwell upon the possible careless actions of a workman, but it has to be remembered that it is after the apparatus is finished and being tested that trouble first arises, and a very serious trouble it usually proves. Firstly, it has to be ascertained what is the cause of the bad or eccentric results. The workman has no knowledge of his blunder or oversight, and the true cause is generally the last thing to be thought of, if it is thought of at all. Usually the faulty part has to be located as nearly as possible, and then the work has to be undone to a greater or less extent. Difficulties of this kind are specially connected with quite new work, but with an apparatus already in use a sudden failure in some direction cannot usually be attributed to defective workmanship. It can be recognised as an inflexible rule that if an apparatus works efficiently once (under ordinary conditions) any fault that may be developed afterwards can rarely be blamed to the construction: it must be due to some other natural cause, an obstruction for instance, unless of course the apparatus has been subjected to an accident.

The causes of erratic results in horticultural works are practically confined to air, or the introduction of some foreign substance, which either checks or for a time stops the circulation. In the latter case it may be leaves or rubbish if ditch or pond water is used at all carelessly. Of course there are other things that will bring about an unexpected stoppage of work, such as a failure in water supply, &c., but with an apparatus which customarily works with steadiness and regularity any little unexpected trouble is usually due to one of the causes named.

Water that is of a varying temperature is always undergoing a change in its aeration, absorbing and expelling air, and on this account the air vents have more use than merely allowing for an escape of air when the apparatus is first charged. Every hot-water fitter knows that when first charging it is sometimes difficult to expel the air from an apparatus, more so than is commonly supposed, and it is understood that if an apparatus is allowed to get a little short of water, so that air enters one of the pipes, some trouble may ensue. When once an apparatus is working with regularity every care should be bestowed upon it to keep it so.

Hood speaks of the phenomena of hot water ascending the return pipe, and the colder water coming down the flow; that is to say, the water in an apparatns circulating in a contrary direction to that which it is intended to do, although the pipes are correctly connected at the boiler. "This," he says, "may arise in an apparatus having but a small motive power, and in which the principle has not been followed out, of making the water rise to the highest point as soon as possible; also having in the flow pipe much more pipe and impediments than in the return, so as to create a greater resistance by friction; and having a greater bulk of water in the ascending pipe than in the return; and also with boilers which are low in depth."

In horticultural works the quantity of pipe, &c., in main and branch flow and return services, is usually about equal, but when there are say five pipes, the odd one is put either in the flow or return according to the judgment of the engineers, some considering one way correct and some the other. In truth, it is doubtful whether with one single pipe there is any noticeable difference either way in these works. A large and well-known firm, who bear a high repute for this work in and around Middlesex, always put the odd pipe into the flow, that is to say, if a forcing house is heated by a branch flow and return service containing five pipes, three would constitute the flow and two the return. This has always proved successful.

This method, however, will appear to be opposed to Hood's argument, but it really is not so, as he refers chiefly to apparatus designed for warming buildings, which have a number of coils, radiators, or stacks of pipe in connection with the main services, and with this he very rightly recommends that, if not all, at least the bulk of these appliances should be on the return. However, this subject will be dealt with separately.

This reversing of the circulation may very likely be due to the use of a very shallow boiler, in which only a small distance exists between the points where the flow and return pipes enter the boiler ; but this of itself would not be sufficient to cause this phenomenon, though it would be favourable to any other cause that might be active. It is an exceedingly rare occurrence, and in horticultural works if the return pipe is found hotter than the flow it may be taken for granted that an obstruction exists—air probably ; or that the supply of water is insufficient, and the flow pipe partially empty.

In experimenting with a small copper boiler having a system of circulating pipes in connection with it the writer on one occasion noticed that the circulation had started the wrong way, and as the apparatus was constructed upon correct principles, and had worked correctly on all previous occasions, it was for the time rather puzzling to fix upon the real cause. The first thought was that some unusual feature might exist somewhere, as the apparatus by much alteration in experimenting had become rather complex, but examination proved that the results should be normal, and no reason appeared for the reversed circulation which was proceeding strongly all the time. The last thing to be noticed was that the lamp was not standing centrally under the boiler, but was giving its heat immediately under the return pipe. The return pipe came through the top of the boiler, projecting down a few inches inside. This was suspected to be the cause of the fault, and further experiment with a simply constructed apparatus showed conclusively that it is not at all difficult to get a reversed circulation by applying the greatest heat to the vicinity of the return pipe.*

In the majority of cases the return pipe enters the side of a boiler, which arrangement greatly obviates the likelihood of this trouble occurring. In very many cases, however, the return pipe, when it comes into the boiler side, has to pass through a flue where it feels a considerable heat, and if by a blunder a vertical portion of this pipe was placed within a flue or in any heated position the effect of the heat would very greatly favour a reversed circulation. In any case it would impair the efficiency of the apparatus, most probably ruin it.†

In works designed to heat buildings of several floors there are many different conditions experienced to what occur in horticultural works. In the latter, as explained, the title of this chapter largely rests with the rise that can be given the pipes, but in buildings of several stories quite new features present themselves. In such works there are usually mains carried either horizontally or vertically, as will be seen in the examples given in a later page. These mains, however, are not always of 4-inch pipe as in glasshouse works, they are usually smaller, and nearly always as small as the engineer dare put them. If too small they will seriously affect the circulation, as can be understood, and it might be prejudicial to have them too large, but this would be a rather rare experience. The sizes of mains are governed by the amount of radiation from the branches they feed. The figures given in a later chapter are based upon the modern type of radiator being used. If plain pipes or pipe coils were to be used the mains would have to be larger, as, for a given surface, plain pipes hold so much more water than radiators. In fixing the size of mains by the radiating surface, all secondary mains or branches should be included in the latter figure. If this is not done allowances must be made when the radiators happen to lie a little extra distance from the mains, and there is no advantage in calculating in this way.

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* These experiments were only conducted with a boiler having the return pipe brought in through the top.

† Of course every practical man avoids carrying the return pipe in any heated position. When it has to pass through a flue surrounding a boiler, it is usual to cover it with brickwork. There is one point in the boiler where the pipe can enter and yet not be subjected to much heat, although it passes through the flue; but in every case a covering of brickwork should be resorted to. This will be more fully explained later.

When the sizes of mains are calculated, the sizes of branches have to be settled, or the good work of the mains may be prejudiced. A table of sizes for branches, both vertical and horizontal, also for radiator connections, is given, and these sizes must be adhered to if the circulation is not to be prejudicially affected.

The sizes of pipes settled, their disposition must be considered, and Hood's recommendation, that the maximum of work (when there is an unequal division) be put on the return services, has an important meaning in every apparatus of the kind being referred to. Taking horizontal work first, a better example cannot be given than what happened in an apparatus erected by the writer. This apparatus was to heat one large floor only, by several radiators which needed to be well distributed. This work was done on the "one-pipe" principle, and to save a little tube the fitters had branched the flow as Fig. 89, instead of branching the return as instructed.

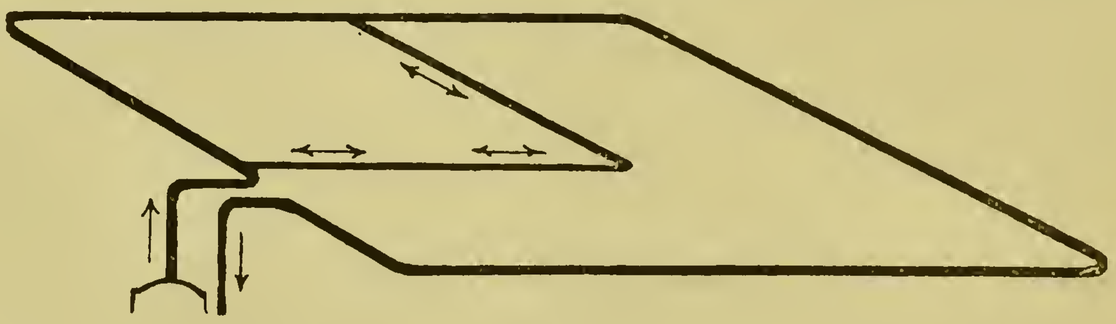

Fig. 89.

The result was that the branch marked with the double pointed arrows remained quite cold, so cold as to make it suspected that its passage was stopped or choked with something. It, however, was found to be quite clear, but although emptied and recharged, and all the air expelled, its contents would not circulate ever so little. Of course, a stop cock put in the branch which took the circulation would have overcome the trouble, but stop cocks should only be put in their proper places. The trouble instantly disappeared when the central branch flow was made a branch return as Fig. 90. The circulation was effective at first trial and has remained so since.

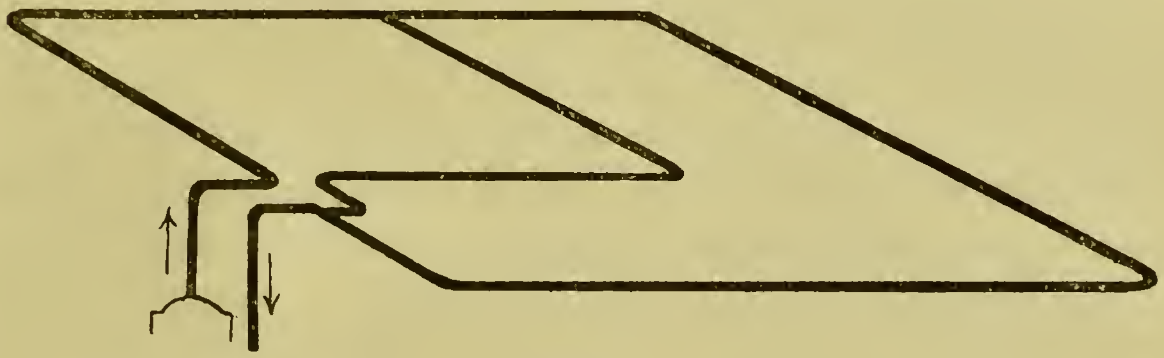

Fig. 90.

With vertical mains or sub-mains the radiator branches are generally connected from flow to return in the usual way, but if an engineer decides to connect his radiators to one pipe only then it must be to the return, as Fig. 91. The wisdom of this is exemplified in the regular and excellent way the "overhead" system of apparatus always works (see examples of apparatus). To put a greater body of water on, or in connection with, the flow pipe which has an ascending current in it, and a lesser quantity in the service which has the falling

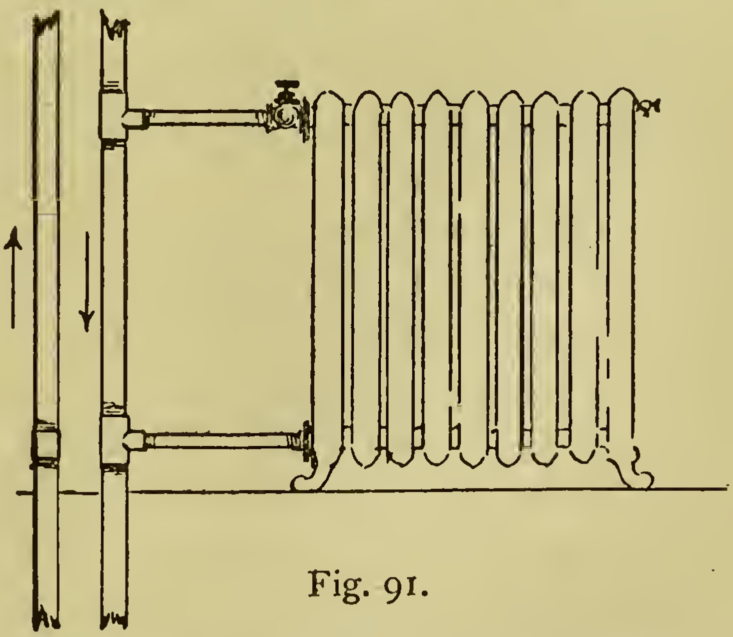

Fig. 91.

water, is contrary to the principles of convection. The falling water is the motive power, and if a large number of branches were on the flow pipe only, it would be possible to get the hottest water round in the return pipe before the cold or colder water was wholly out of the flow and its branches.

Of course, the amount of heat lost from mains and branches before the water reaches the radiators (where the heat should all be delivered) always affects the circulation more or less. It would be a most commendable thing if a rule could be instituted that main flow and branch flow pipes be always covered with some poor heat-conducting material to prevent loss of heat. The effectiveness would be so increased and the consumption of fuel decreased, given results would also be obtained in less time. The return pipes might also be covered, for what heat they lose is heat wasted. Certainly, the cooler the return pipe the more effective the circulation, but the circulation in vertical works should always prove good without wasting fuel to make it so. Loss of heat from the returns does not, however, go to prejudice effectiveness to the extent that loss from flow services does.

In works erected in brick buildings it is an almost invariable rule to use wrought-iron tubes for the services, unless the apparatus be a very extensive one when cast pipes are sometimes used for the large mains and wrought iron for the smaller branches. With wrought tube a failing which affects the circulation appears in the fittings which are not at all favourable to the results aimed at. Of course, with so much vertical pipe the circulation itself is strong enough to bear reducing in many cases, but this, after all, is no reason why it should be reduced by fittings of bad interior form.

Taking bends first, the wrought bend, which is a piece of tube bent to a nice easy sweep, is an excellent fitting, as offering the least possible resistance when the direction of the circulation has to be changed. Bends, however, cannot be used everywhere, and at many points elbows have to be resorted to, and the "round elbow," as it is called, is a poor shape compared to those used in America. Fig. 92 is a section through a wrought-iron elbow of this kind, and the irregularity of the inner surface at the angle is nearly always present, being caused in manufacture. In America wrought fittings are seldom used as they consider cast malleable iron, or heavy soft cast iron, better.* A section of an elbow of either of the latter make is as Fig. 93, and the inner surface is smooth and of as good a sweep as can possibly be got in this compass.

A branch fitting is, we may say invariably, a T-piece, and although these do not retard the general circulation of an apparatus they affect that within the branches, especially if the branch is from a vertical main. The water circulating up and down vertical mains is travelling in a way that is the natural motion of convection, and that of the flow pipe will not readily enter a branch at right angles with such an abrupt opening as is offered by an English T-piece. With malleable or cast fittings we can have Y-pieces or 45° branches and other forms of fittings that will be found described in a later chapter, and a much more free and regular circulation can be obtained at all points. The circulation, either wholly or partially, can be materially affected by the fittings used, and the section which deals with these can be perused with advantage.

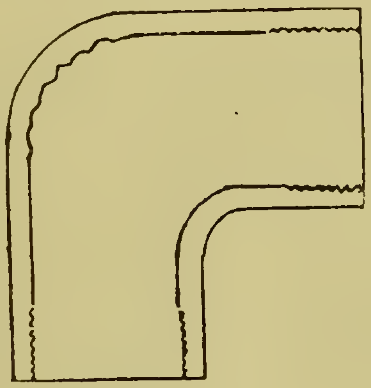

Fig. 92.

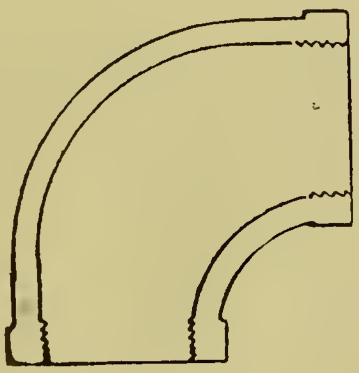

Fig. 93.

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* American practices in hot-water works are worthy of every respect. Their experience is wider and the demand for this method of heating vastly greater than in England. Their fittings and appliances are equally advanced.

CHAPTER VIII.

APPLIANCES AND FITTINGS FOR HORTICULTURAL WORKS.

Hot-water pipes and fittings—Price list—Jointing pipes—The rust joint—Red and white lead joint—Rubber ring joint—Improved expansion and other joints—Stop valves and their uses—The throttle valve—The slide valve—The medium screw valve—The reliance valve—Furnace fittings.

A PECULIAR source of trouble sometimes occurs with ordinary cast hot-water pipes, by reason of the varying thickness of the substance of metal in the castings, and the difference is particularly noticeable between pipes and fittings, the former being frequently lighter or less in substance than the latter. It is to be presumed that either the moulders at the foundry are paid differently for pipes than for fittings—such as paying by the piece for pipe and by weight for fittings—or it is a sign of careless work in the moulding shop and a proportionate waste of material. Nothing is gained by the fittings carrying this surplus metal, and it is always a source of trouble by reason of the extra work it entails in making joints. Sometimes there is a $\frac{3}{8}$-inch space for the jointing material, sometimes the spigot end of the pipe will only just pass into the socket, and this is particularly unfortunate with rubber ring joints, as will be learnt directly.

Another ill practice that has been a little prevalent is in sending out pipe insufficient in diameter and weight. No doubt it is brought about by competition, but it never need be feared with any firm of good standing. A 9-foot length of 4-inch pipe should weigh 98 lbs.,* and its size, 4 inches, is internal diameter in the pipe portion (not in the socket).

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* See Appendix.

This pipe differs considerably from cast smoke pipe, also from the pipe used so extensively for conveying rain water from roof gutters to the ground, both these latter being of a much lighter quality ; and, as a rule, the pipe for hot water is cast from different metal of a somewhat finer quality. Nearly every make of hot-water pipe has two or three (usually three to a 9-foot length) bands or rings cast round the diameter of the pipe, one at the opposite extremity to the socket, and two at equal distances between. The socket is considerably larger than the pipe (compared to the other two qualities of pipe mentioned), so as to admit the ringed spigot end and give sufficient room for the jointing material and the tool with which it is caulked. There are no flanges for securing the pipe to wood or brickwork like the rain-water pipe. The socket should be particularly strong, with two cast rings formed round it and with strengthening bars between them. The different varieties of patent joints, expansive and other kinds, will not, of course, be found to answer to this description correctly, but they should be equal in strength and quality.

The following list comprises all the fittings in general demand, and is compiled from the catalogue of a well-known firm. The prices shown may be considered as the average cost of these goods of a satisfactory quality, and will be found useful for reference when estimating, &c.

PRICED AND DESCRIPTIVE LIST OF HOT-WATER PIPES AND FITTINGS OF THE ORDINARY KIND.

(These prices are subject to a discount to the trade.)

		2 in.	3 in.	4 in.
Hot-water pipe, 9 ft. lengths	per yd.	..	2/3	2/8
" " 6 ft. "	"	1/6½	2/3	2/8
" " 3 ft. "	"	1/9	2/6	3/2
Hot-water spigot or coil pipes 3 ft. 6 in. to 5 ft. 6 in.	"	1/6½	..	..
Hot-water spigot or coil pipes, 2 ft. to 3 ft.	"	1/9	..	..
" " " 6 ft. to 9 ft.	"	..	2/3	2/11
Trough pipes, 9 ft. lengths	"	..	7/6	9/
" 6 ft. "	"	5/	7/6	9/
Loose trough, 2 ft. 6 in. to fit on pipe ..	each	3/3	4/	5/3

Curved pipes made to any radius to order.

No.			2 in.	3 in.	4 in.
2	Elbows, common	each	1/8½	2/9	3/5
3	„ double socket	„	2/1	3/1	4/3
3*a*	„ „	„	3/4	4/6	5/6
3*b* & 3*g*	Elbows, ⅛ circle inside	„	2/3	3/9	5/
3*c* & 3*h*	„ „ outside	„	3/7	5/6	6/6
3*d* & 3*i*	Bend, octagon	„	2/6	3/9	5/3
3*e*	Elbow, double socket	„	..	8/6	11/
3*f*	„ „	„	..	11/	13/6
4	„ long	„	3/	4/3	5/3
4*a*	„	„	..	7/6	10/
4*b*	„	„	..	10/	13/
5	„ double	„	3/3	5/3	7/6
5*a* & 5*b*	Swan-necks	„	4/3	6/9	8/6
5*e*	S-Pipe	„	4/	6/3	8/
6, 7 & 7*a*	Elbows. Flange and socket and spigot	„	3/9	5/	6/3
8	Flange sockets	„	2/6	3/9	5/3
8*a* & 8*f*	Short flange sockets, for coil connections	„	2/3	3/6	5/
8*b*	Flange spigots	„	2/6	3/9	5/3
8*c*, 8*d* and 8*e*	Boiler tops, or hat pipes, straight and elbowed	„	4/	5/6	7/
9 & 9*b*	Branch pipes	„	4/3	7/	9/3
9*c*	Branch pipe or Y-piece	„	2/9	4/9	6/3
9*d*	„	„	7/6	10/6	15/
10, 10*a* & 10*b*	T-piece	„	2/6	4/2	5/3
11 & 11*a*	T-piece	„	2/6	4/2	5/3
11*d*, 11 *g*	Cross-piece	„	4/6	7/6	10/
11*i*	Cross-piece	„	5/3	8/6	11/
11*e* & 11*f*	H-pieces, open and close	„	5/9	8/6	12/
12	Double collars	„	2/	3/	4/3
13	Single „	„	1/	1/9	2/3
13*a*	„ „ long	„	1/5	2/	2/6
14	Blank sockets	„	1/1½	1/9	2/3
14*a*	„ spigots	„	-/7	-/10½	1/6
15	Close syphons	„	2/6	4/	5/
16	Open „	„	2/9	4/9	5/6
16*a*, 17*a* & 17*e*	Open syphons, with outlets	„	4/9	7/6	10/
17, 18 & 19	Elbowed and outlet syphons	„	4/3	6/9	9/
17*c* & 17*d*	Chair syphons	„	4/6	7/6	10/
20	Three-way syphons	„	5/	8/6	11/
21, 21*a*, 22, 23, 23*a*, 23*b*	Three-way syphons, with elbows and outlets	„	7/	10/6	14/6
24	Four-way syphons	„	7/	11/6	15/6
25, 25*a*, 25*b*, 25*c*	Four-way syphons, with elbows and outlets	each	8/6	14/6	19/6

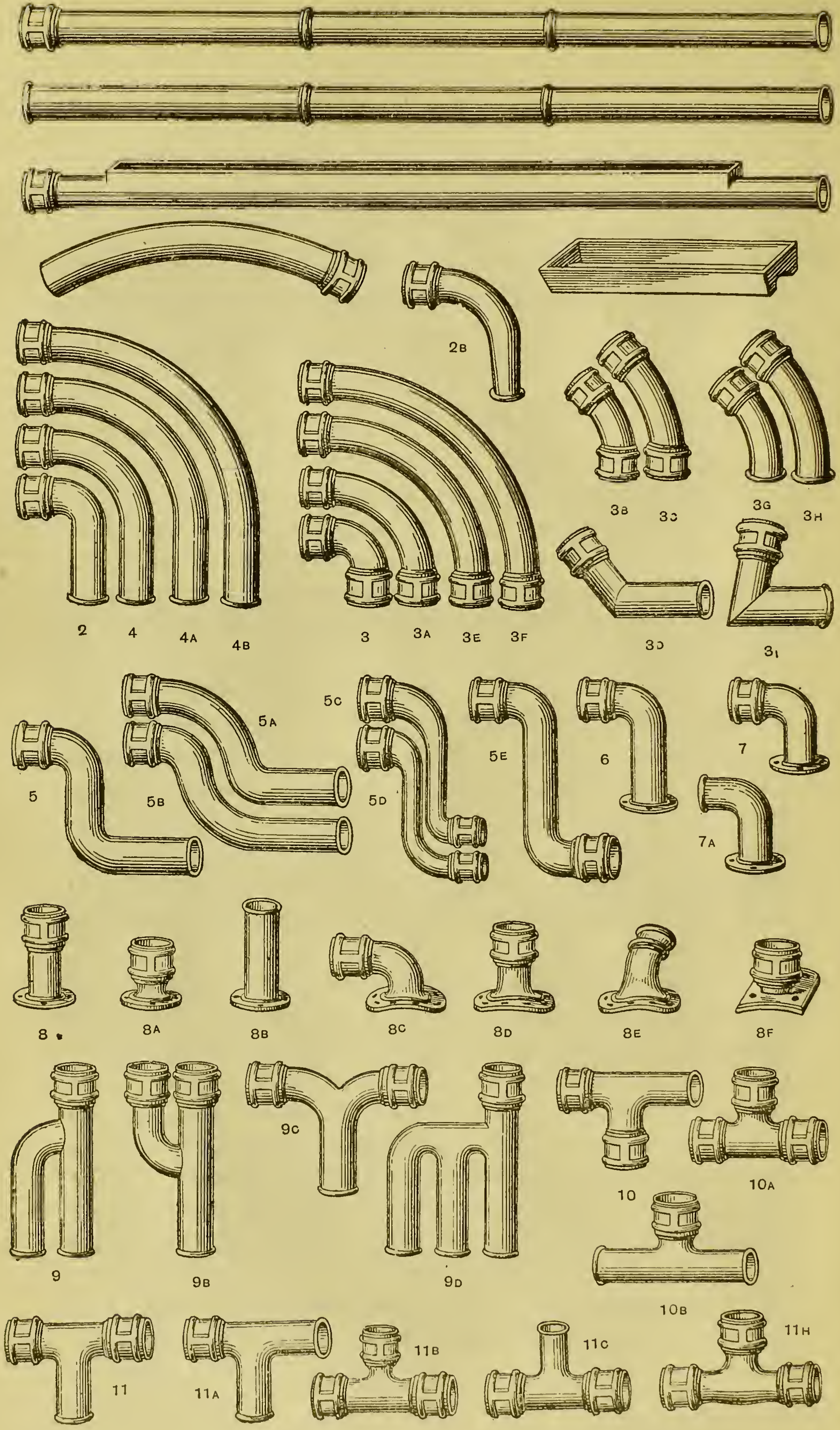
Diminishing Connections.

No.		3 to 2,	4 to 2,	4 to 3 in.
2*b* Elbows	each	3/6	4/6	6/
5*c* & 5*d* Elbows	”	6/9	8/6	9/6
11*b*, 11*c* & 11*h* T-pieces	”	3/	4/9	6/
14*b* Sockets	”	4/6	5/6	6/
14*c* ”	”	3/	4/	4/
14*d* & 14*e* Pipes	”	3/	4/	4/
14*f* Nipples	”	2/	2/6	2/6
17*b* Elbows	”	..	10/	12/6

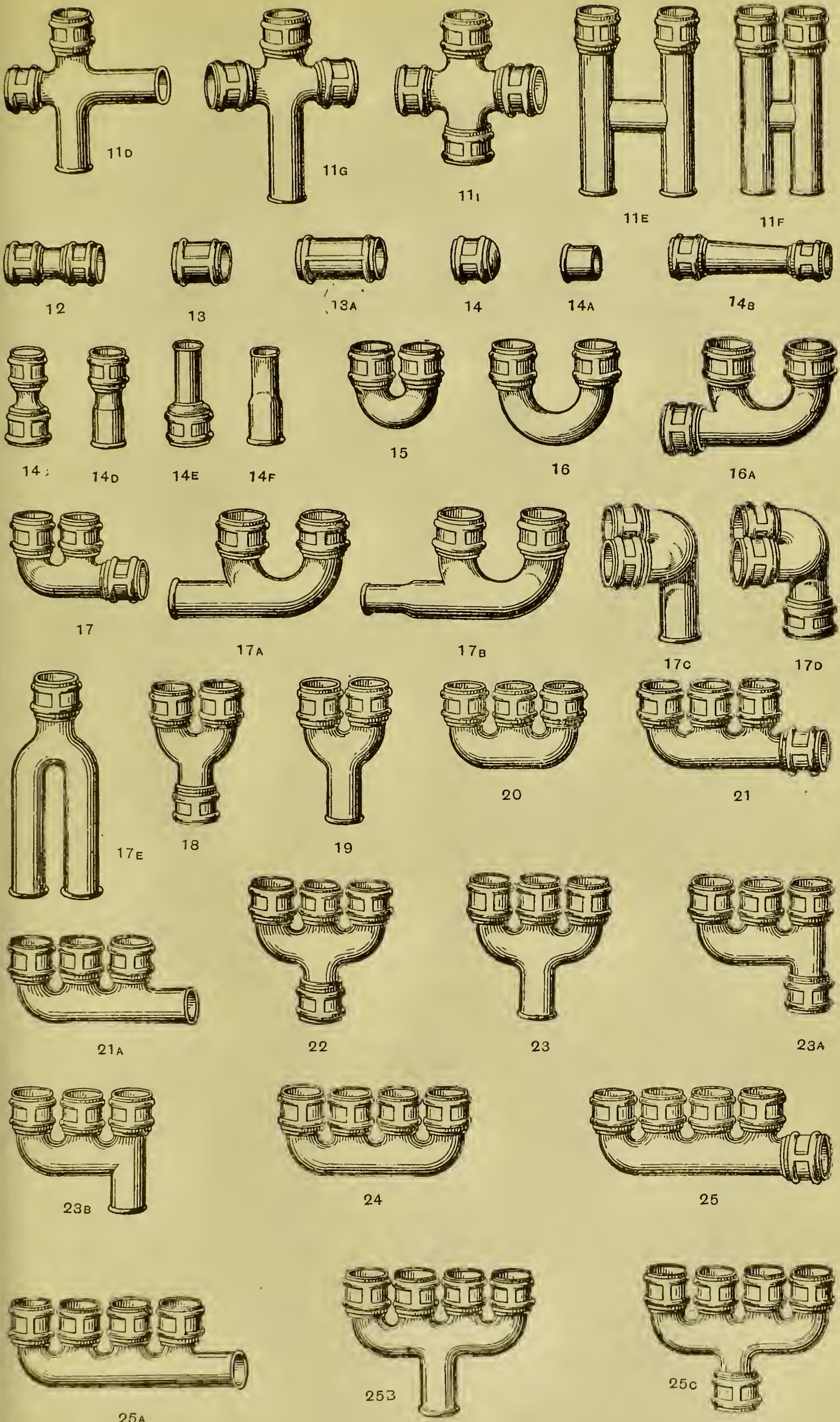
There are several ways of jointing this ordinary description of socket and spigot hot-water pipe, almost every hot-water fitter having some special ideas of his own as to the nature, quantity, or admixture of the material. But in general practice it will be found that the methods are confined to three, viz. the iron borings or rust joint, white and red lead, and the rubber ring. With the two former, hemp, yarn, or gaskin requires to be used with the materials named, but the latter is commonly used by itself. It will be understood that although these joints have to be watertight, they have but a trifling pressure to withstand in glasshouse work, very different to what the pipe joints experience in a building that has several floors heated from one boiler. It is quite possible to make a sound and lasting joint with the yarn only where the pressure is so low.

The cheapest joint is that made with iron borings, as the material costs so little ; but the joint is seldom used when the apparatus is a small one, as will be explained. The joint is made by mixing with iron borings (which require to be pounded if very coarse) some sal-ammoniac and sulphur, both in a powdered form. When the whole is moistened with water the two latter materials bring about a chemical change in the borings, causing them to set hard and solid, or, in simple language, causing the borings that are driven into the socket joint to rust up into a solid mass.

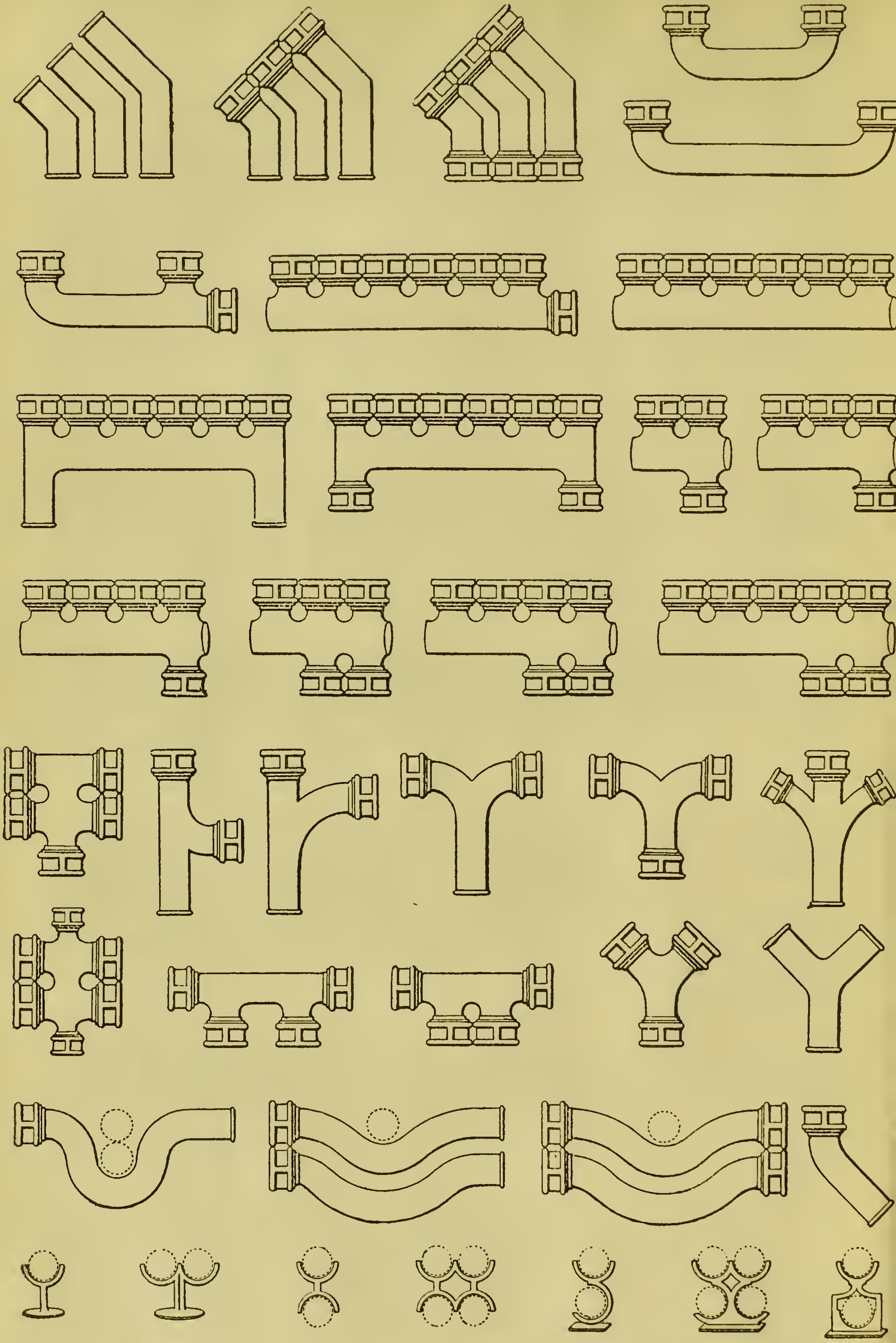
This rusting process takes place slowly, or rather, it is some time before the chemical action quite ceases, although



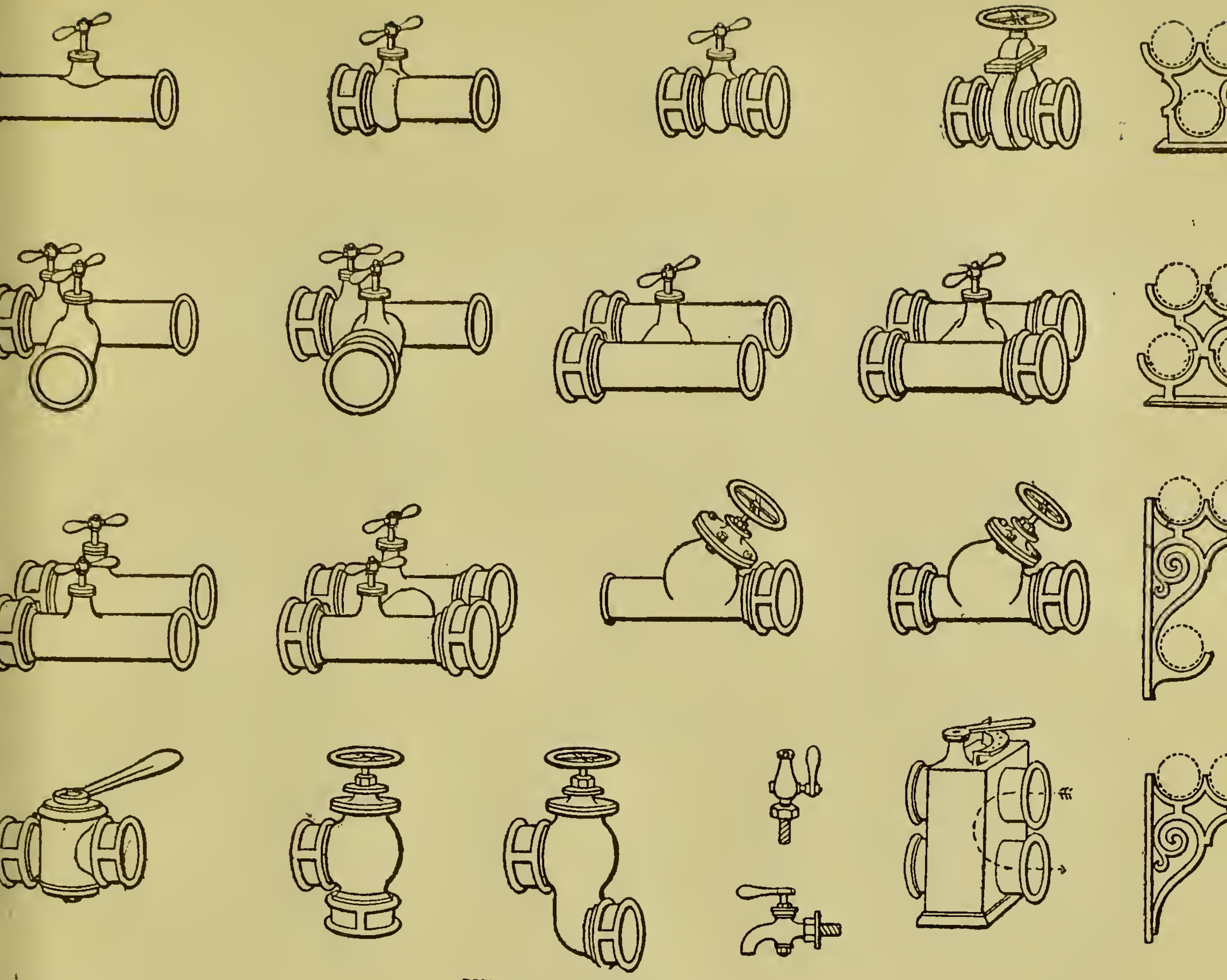
GENERAL IRON FOUNDRY CO.'S CASTINGS—HOT-WATER PIPE CONNECTIONS.



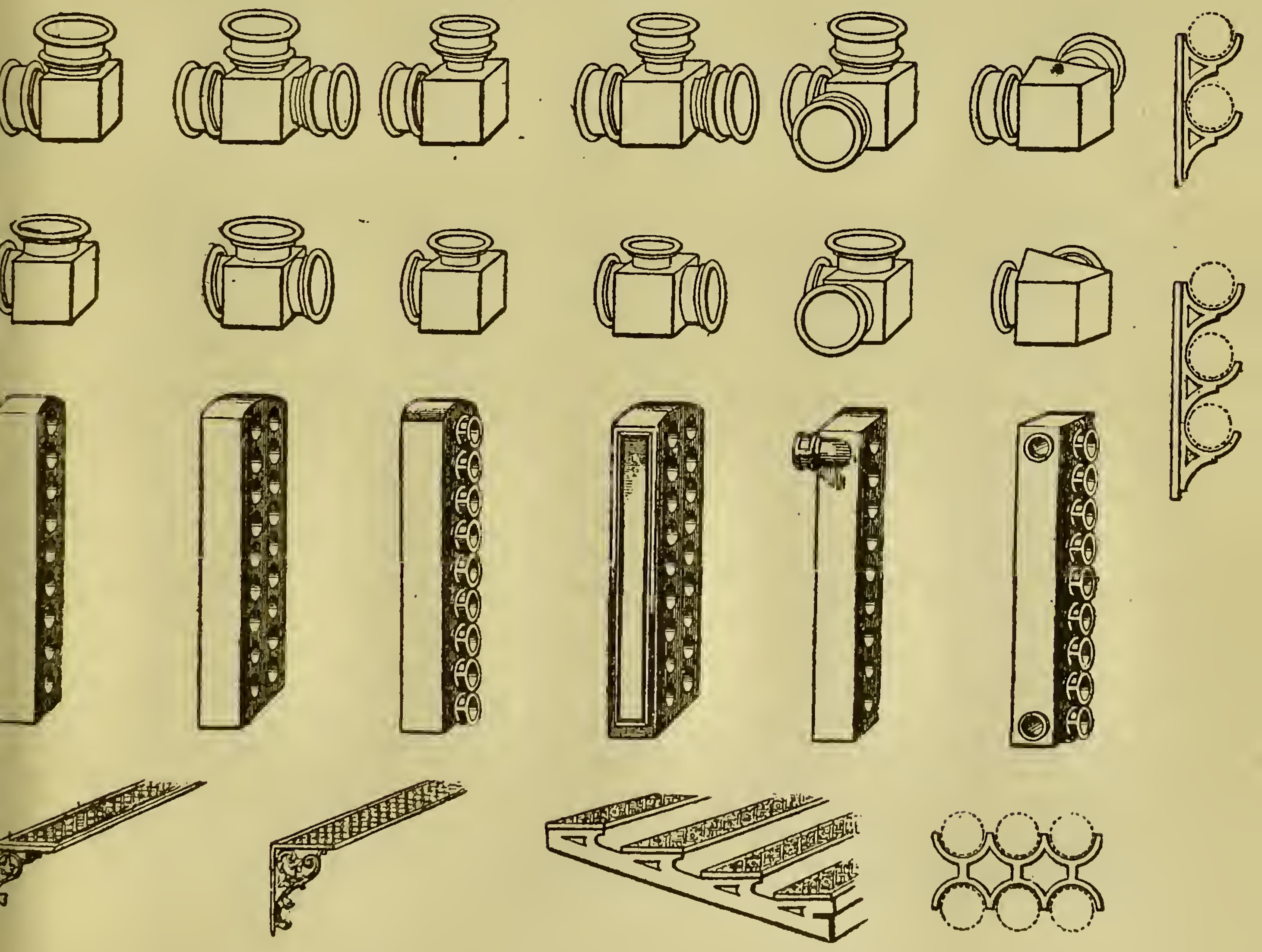
GENERAL IRON FOUNDRY CO.'S CASTINGS—HOT-WATER PIPE CONNECTIONS.



MACFARLANE'S CASTINGS — HOT-WATER PIPE CONNECTIONS



JUNCTION BOXES.



MACFARLANE'S CASTINGS —HOT-WATER PIPE CONNECTIONS the joint may be quite rigid in a short time. As the change takes place the materials expand slightly, so it is very necessary that this joint be made skilfully, or the sockets will be split. It is fair evidence of a man's good workmanship if his rust joints are made soundly, yet do not afterwards split open, for it is no exaggeration to say that many thousands of lengths of pipe have perished from this cause.

Some workmen consider that it is proper to first caulk the joint half full of yarn, the remaining half with borings ; others say three-fourths of yarn, and finish off with a fourth (about $\frac{3}{4}$ inch) of borings. Occasionally only half an inch of the joint is of this latter material, and sometimes a joint may be met with having first about one-third yarn, then half an inch of borings, then a little more yarn, and finishing off with more borings. There is no doubt that three-fourths yarn and one-fourth borings makes a sufficiently sound joint under ordinary conditions, but it is better to make one-third borings the least quantity,* although the less the quantity of this material, the less the liability of the socket being afterwards fractured. The borings once prepared cannot be kept except for a very short time, as they set hard quickly.

This joint costs the least in materials, and is generally considered the cheapest in the end ; but when we take into consideration the time occupied, the cracked sockets (each of which, of course, ruins a whole length of pipe), the inability to afterwards disjoint the pipe for alteration or repairs, &c., it is doubtful whether its cheapness is as real as it looks. The proportions usually laid down for making the rust joint are, by weight, one part powdered sal-ammoniac, two parts powdered (flour) sulphur, and 80 to 100 parts borings ; thus 1 cwt.

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* There is no doubt that the yarn by itself makes these joints water-tight, the borings only acting as a support to the yarn, or to keep it sound and the pipe rigid. The writer once saw some joints made with old rope material caulked in, and when, in experiment, it was subjected to 30 lbs. pressure per square inch, it was perfectly sound, and had ultimately to be burnt out before the pipes could be separated.

of borings would require about $2\frac{1}{4}$ lbs. of sulphur and fully 1 lb. sal-ammoniac, and the whole must be moistened and thoroughly well mixed. These proportions are not fixed with any exactness; if they vary a little no harm results. In fact, when the mixing is left to a workman, he judges (from previous experience) what is needed, and puts, say, a handful of one material to so much of another, calculating the aggregate amount by pailfuls very commonly. If the mixture is too strong, a fracture may ensue, but if a little too weak, it only takes a little longer in setting. It requires to be made from half an hour to two hours before use, according to the weather, and it cannot usually be kept longer than one day without becoming hard.

The joint for general purposes, and which has considerable use at present, is that made with white and red lead and yarn,* this being more simply made than the last, safe in results, not so very hard and rigid, and there is no after-action to endanger the sockets. The materials are a little more expensive than the rust joint.

In making this, the white lead, which is a soft, sticky mass, is mixed with sufficient dry red lead to make a mixture of about the substance of putty when they are incorporated together. It is then desirable to mix a small quantity of this material with boiled oil to form a thick liquid paint to coat the socket and spigot with before the jointing material is inserted. Next a length of yarn is well caulked in, then a layer of the lead mixture is introduced, then another length of yarn, and so on, until the socket is filled, finishing off with the lead. This, when dry, is a very sound and durable joint, and at present is much in favour if the cost will admit. It is the material just mentioned that is used, with a little loose yarn, to make the joint where the flanged socket is secured to the boiler.

The next joint to be spoken of is that which consists merely of an indiarubber ring, the rubber being circular in section, so that when stretched over a pipe it can be made to roll up and down with moderate ease. This joint is made by stretching the rings on to the extreme spigot end of one pipe, then forcing it into the socket of the next. This is sufficient to make a water-tight and sound connection, the rubber being of a proper thickness (about ½ inch) to effect this. If, however, the castings are of irregular size, as explained, it may happen that the space left in the socket is insufficient for the ring to pass in, even if the edge of the socket is chipped round, and great force is used in the endeavour to insert it. This is a drawback to the use of the rubber ring joint, but fortunately not a serious one. Oftentimes the space within the socket is just sufficient to admit the spigot and ring upon it if great force is used. In this case the ring is flattened out and makes a joint of decidedly sound character, but one that would be difficult to undo after a little time.

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* It should have been mentioned that the yarn is readily procurable adapted for this purpose; it is used in pieces about a yard long.

The chief objection to this rubber ring joint is its want of rigidity, as it affords no support whatever to the pipe, and some form of bracket or pipe-stand is needed almost at every length, unless the pipe happens to be laid on a flat surface, or in a trench. But notwithstanding this, the joint is a very convenient one ; it is durable (for the rubber adheres to the metal after a time), and it is easily and very quickly made. It is the kind of joint provided with small independent boilers that are sold with pipes complete for erection by an amateur in his own greenhouse.

This joint does away with the necessity for any device providing for expansion, as every joint in the whole apparatus is a provision in itself. The cost of material (the rubber) is more than that for a rust joint, but the greatly lessened time and the complete absence of risk, equalises the ultimate expense in each case. Many engineers are using the ring entirely now, as, provided they have a careful foreman, only indifferent labour is needed for joint-making. When there are a large number of joints to be made, a "ring expander" is used, as Fig. 94, the rings can then be rolled on, which is better than stretching them on with the fingers—an awkward method, causing the rubber to get twisted.

It is almost needless to add that there are other methods of jointing the ordinary socket pipes, by patent cements, &c., but the common and general methods are all that can be safely spoken of. As already mentioned, old rope, untwisted, will make a better joint than yarn ; and there is not the least doubt that tarred rope, old tarred scaffold cord, &c., would, under ordinary circumstances, make a good joint by itself.

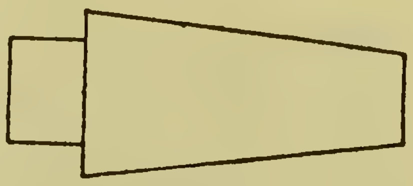

Fig. 94.

The particular and valuable use of a reliable elastic joint, as we get with a rubber ring, or one of those about to be mentioned, is that the expansion and contraction of the pipes can take place freely, and without any injurious effect. With the fluctuations of temperature that are constantly taking place to a greater or less degree, we get a constant, though almost imperceptible, movement of the pipes, sufficient to ruin any rigid joint in a comparatively short time if the run of pipes be anything but short. We have to remember that the flow and the return pipes are never of an equal temperature, and that the movements or strains brought about by the variations in heat are irregular. This tends to make these pipes, which are connected at both extremities, injure one another, as they do not always act in unison either as to time or extent.

In arranging to obviate this ever-present trouble, different engineers have again different ways of proceeding. One large firm of growers* that the writer came in contact with would not permit of a rust joint being made on their premises ; their joints were made, some with red and white lead, and some with rubber ring, a rubber ring at about every sixth joint as a provision for irregular expansion, as explained.* Another firm preferred to use both red and white lead and rust joints, one of each alternately, and this, of course, was satisfactory; but long loose sockets were provided, packed and arranged as stuffing boxes, to allow the pipes to have a slight movement in them as they expanded lengthwise. Great care has to be exercised in this matter if three or four pipes are carried one above the other, connected at their extremities, and are likely to be of different temperatures.

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* Large horticultural establishments always keep their own staff of fitters, under a foreman engineer ; and there is ample work for several men at many such places, where there may be perhaps fifty boilers in use, with miles of piping.

A good form of patented expansion joint is as illustrated, Fig. 95.† This consists of two cast collars, an iron ring, and two rubber bands, the drawing together of the two cast collars compressing the rubbers and effecting a sound joint. The particular advantage of this joint is the fact that it is used with perfectly plain pipes, no sockets being needed, nor need the pipe ends be perfectly regular or cleanly cut. In addition to this, as the pipe is independent of sockets or special ends, there is no occasion to order or wait for certain lengths, as the plain pipe can be readily cut and inserted at once. Lastly, the joint permits of any length being taken out for repair, or in case of leakage, &c., without disturbing any other parts of the service—no mean advantage, as any one will acknowledge, if, after laying down a long length of the ordinary pipe, a bad leakage is found somewhere about the

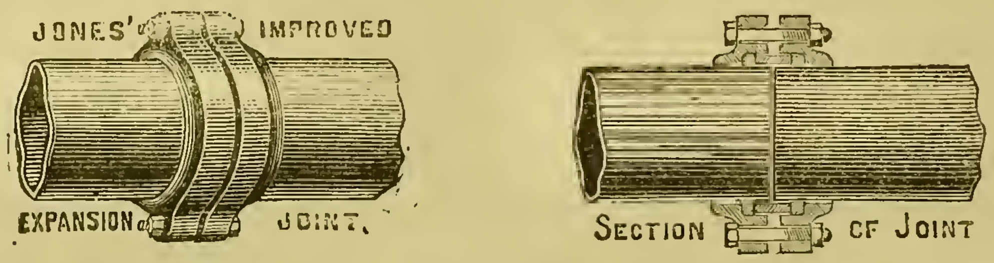

Fig. 95.

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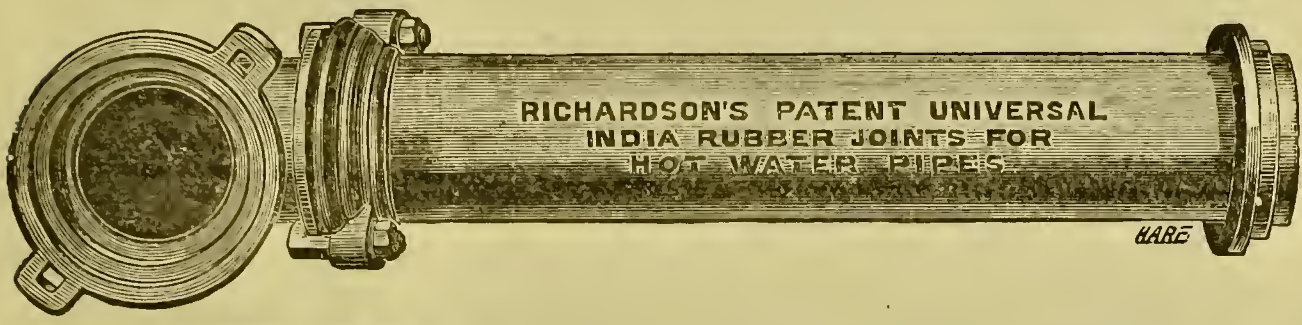
* If the expansion in both pipes was equal, expansive joints would not always be needed, as the roller bearings to the supports would give freedom of movement; but even this would not suffice always, as the extension of a long length of pipe might injure the branch services from it.

† From the catalogue of Messrs. Jones and Attwood, of Stourbridge.

middle.* This form of joint, while suited for low-lying works, will not withstand pressure.

A good form of expansion joint is Richardson's patent, as shown in section at Fig. 96.† The lengths of pipe have specially formed ends which, when clipped together, compress an india-rubber collar between them as shown. Only one rubber collar is needed, and a very sound joint is effected, capable of withstanding pressure. This joint is now largely used in Government departments, and has a considerable demand. It is quite suited for works that cause heavy pressure to be exerted in the pipes.



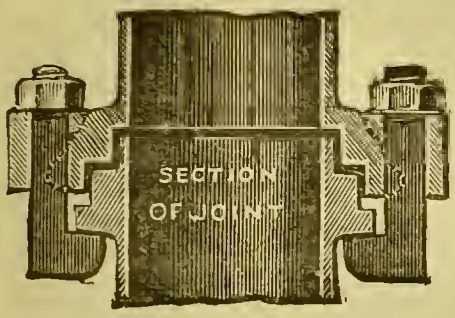


Fig. 96.

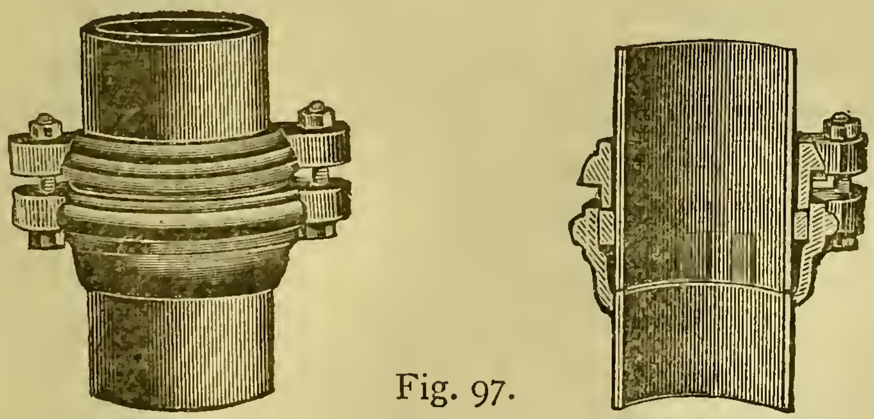


Fig. 97.

Fig. 97‡ is Messenger's Pattern Expansion Joint, differing from the others in detail, but of similar effectiveness and capable of bearing pressure when required. One end of each pipe is plain, which admits of cutting and shortening when required. All joints, which have special end castings to both ends of the pipes, prevent cutting or shortening on the job, but all lengths are kept in stock by the makers to fulfil any requirement.

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* Loose sockets have to be provided at regular distances, in long lengths of pipe, jointed in the ordinary way. These act as unions, and can be moved to disjoint the service.

† From the catalogue of The Meadow Foundry Company, Limited, Mansfield, Notts.

‡ From the catalogue of Messenger & Co., Loughborough.

STOP COCKS AND VALVES.

In an earlier part of the book these two fittings were mentioned indiscriminately, without regard to whether the circumstances made a valve or a cock desirable. It can now be explained what the difference between the two is, and their respective uses can be shown.

The term "stop cock" is sometimes used in horticultural works, but the term is an incorrect one, as a stop cock, in the proper sense of the word, is not usually met with in this work. They are really all stop valves, but of two kinds—one the "throttle," and the other some form of screw-down arrangement which shuts off the circulation of water perfectly, which the throttle does not. The throttle valve is the most used, partly on account of its being the least expensive of any reliable kind, partly because of its simple working, and that all gardeners are familiar with it; also that, in certain cases, the fact of its not shutting off dead is a favourable feature. There is a stop valve made for use with radiators which, by means of a small hole in the seating, permits a feeble circulation to occur when the valve is closed. The object of this is to prevent the contents of that part of the apparatus being frozen, if the valve is closed and forgotten.

The throttle valve has this advantage, and it is seldom that any part of the apparatus has to be shut off soundly, when it is once in regular use.

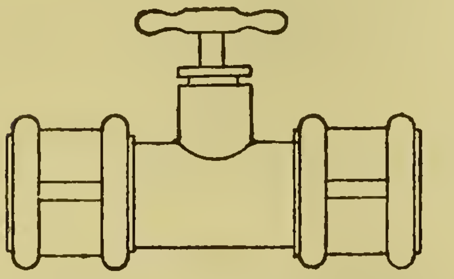

Fig. 98.

Fig. 98 illustrates a throttle valve, it being a short length of pipe with a disc of metal within it operated by a handle, its simple construction keeping the cost as low as possible—an important consideration in low-lying work, which will not always permit of using valves of a smaller size than the service pipe (as we can in heating buildings); the cost of a moderate quality valve of a 4-inch size is as much as 15*s.** In the ordinary throttle valve just illustrated, the disc, which is turned in a lathe, is made to fit the opening in which it works as closely as possible; but it cannot be made water-tight, as allowances have to be made for expansion of metal, &c. No opportunity must be given for the working parts to get bound up in any way, as these valves, when once set to the requirements, may not be afterwards operated very often, although, properly speaking, they should be looked to and tried very frequently.

The fact that a throttle valve does not perfectly shut off the circulation is not a very great objection in some horticultural works, as just explained, for the circulation, although it may be good in the ordinary sense of the word, is not very rapid. It is, therefore, easily checked or stopped to such an extent as to prevent any very noticeable movement past the valve, and the water passes on in other directions freely, its impetus not being sufficient to force a great amount past an obstacle. In a vertical apparatus, even of moderate height, the circulation is of sufficient strength to effectually work through a very small opening, which permits of the use of smaller pipes between the boiler and the radiating media, and also smaller valves, without impairing results.

The use of throttle or perfect valves is another question generally decided by the gardener in horticultural works, and their use is greatly governed by what is to be stocked in the houses, some gardeners contending that a slight variation or irregularity in temperature is sufficient to interfere with the steady progress of the plants. When such care as this is needed, the gardeners will not admit a throttle valve of any description.

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* Occasionally valves of a smaller size than the service pipe can be used, but rarely with extensive works in glasshouses, where the motive power is low.

Fig. 99* shows a throttle valve similar to that just described, but having facilities for removing the disc or working portion for repairs, or for easing the working parts when too stiff, &c. This is a decided improvement, as the ordinary description of these valves are far from simple to get at when attention is needed; whereas this one, as the illustration plainly shows, makes the task quite an easy one. This valve, as well as the one last explained, has a stuffing box at the point where the rod of the handle passes through the substance of the pipe. Without this, of course, it would be difficult to make it water-tight, and the stuffing box is also required to make the valve work steadily. It is usual to have them work rather stiffly, so that there may be no risk of the disc moving from any accidental cause after it has been set by the gardener.

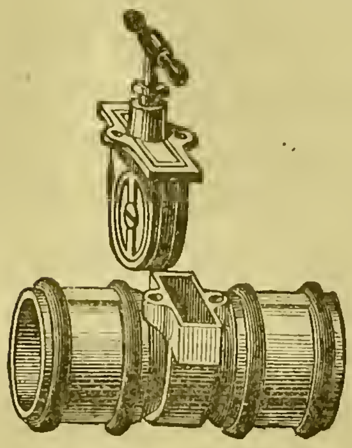

Fig. 99.

Fig. 100† illustrates what is commonly called a slide or gate valve. This is a valve of the "perfect" kind, which does not permit of the water circulating past it when it is

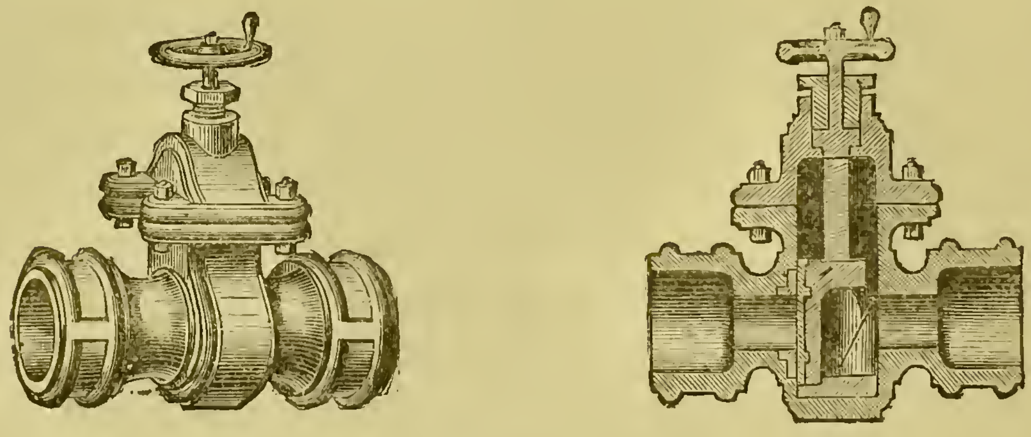

Fig. 100,

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* From the catalogue of Messrs. W. G. Cannon & Sons, heating engineers, London Road, Southwark, London, S.E.

† Also from Messrs. Cannon's catalogue.

closed. In the illustration it will be noticed that the circulation through the barrel of the valve is checked or cut off by a slide or door, which is caused to move downwards by the screwing down of the wheel handle (the valve being, of course, opened by reversing the motion). This permits of the movement in the water being regulated to the greatest nicety, and gardeners who require great exactness in results are able to get it with a valve of this kind. This valve is used to a very considerable extent.

Fig. 101* is a screwdown valve which shuts off the circulation perfectly (even more perfectly than the last), as the seating is turned and faced with rubber. It is an effective valve, but one which has a clear straight way through it is preferable.

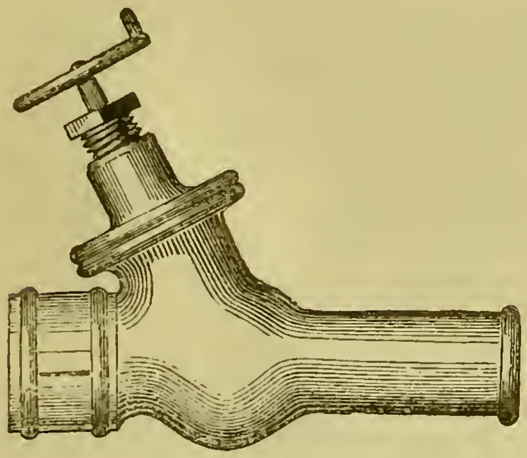

Fig. 101.

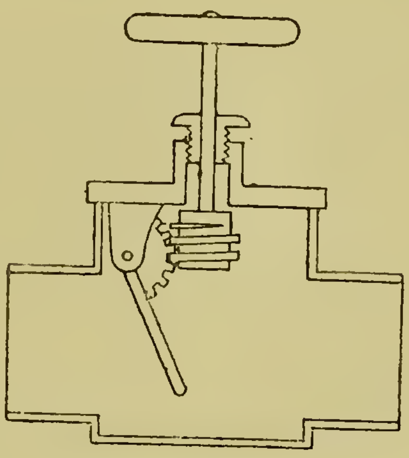

Fig. 102.

Fig. 102 is another valve of the "perfect" kind, its working parts being a disc, with a turned face, and hinged at the top edge. Sometimes the valve is faced with rubber and the opening and closing of this disc seating is effected by an ingenious thread and tooth gear, as shown. This has a straight passage through it, but it requires to be mentioned that all valves faced with rubber should have fairly constant use, or the seating will adhere to the metal it presses against if left closed, this result being accelerated by heat.

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* Also from Messrs. Cannon's catalogue.

The last that needs mentioning is as Fig. 103,* a novel arrangement, effecting a considerable saving in H and T-pieces, which very usually require two and three valves each to do what this does with one. It is in reality a double or treble-acting throttle valve, the disc being replaced with two leaves placed at right angles or in a line, as shown. With the T-valve a quarter turn of the handle sends the water in either direction, but it can be placed so as to permit circulation in all directions if required. With the H valve the action is different, a quarter turn of the handle permitting the water to either pass along the flow and return past the valve (as illustrated), or, on the other hand, causing it to pass from one pipe to another without passing the valve, thus effecting precisely the result that three valves are required to do in the ordinary H-piece.

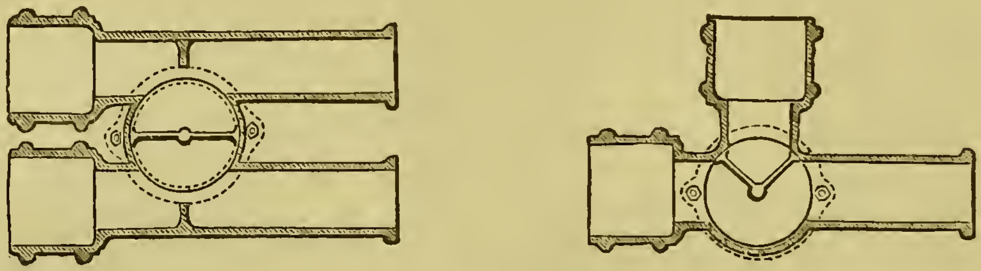

Fig. 103.

There are other forms of valves, as will be seen on the sheet of Macfarlane's fittings, but it is needless to describe them all here. What is required is to explain the different acting principles upon which the majority are constructed. Undoubtedly the ordinary throttle valve has the greatest use of all of them; but, as explained, this is to a great extent due to its lowness in price. Although it was pointed out that some gardeners require the greatest exactness in temperature, this is only in cases where the most delicate things are being reared, or some important feature is being developed. With many of the common articles that come from glasshouses, a little irregularity is not minded, as they may be tolerably hardy, and only require to be protected against the severe cold of night or winter.

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* The "Reliance Valves," from the catalogue of the Thames Bank Iron Co., Upper Ground Street, London.

The throttle valve * has the advantage of a screw-down valve in indicating by the position of the handle the extent to which it is opened or closed. The screw-down arrangement does not do this, and if in doubt, the attendant has to try it by screwing the handle up or down to ascertain how much it is opened or closed. But when the screw-down valve is in use, the gardener soon ascertains how many turns the handle requires for the result he wishes to obtain. It may be mentioned that valves are made to meet every requirement, for corners, upright, in box-ends, &c.

The valves here mentioned are seldom used for hot-water works in buildings where smaller pipes are introduced between the radiating media and the boiler. The valves for that work will be referred to when that subject is treated.

Although mentioned before, it will bear repeating, that it is not sufficient to put a valve in the flow pipe only—there must be one in both flow and return, or the hot water will find its way up the latter pipe, and produce very annoying results. If throttle valves are used, it becomes, if possible, even more necessary.

FURNACE FITTINGS.

The variety of these is very limited, and at present there seems no demand for any extensive improvements. They do not seem to create any particular feeling of competition, as the same patterns can be got from nearly every maker, appearing, with little exception, as if all were made from the same design. Fig. 104 † shows the oldest form at present in use—a cast frame, and two cast doors with wrought hinges and fittings. There is, or should be, a shield plate, properly affixed to the inner side of the upper door, otherwise the heat will soon

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* This valve has a very straight and full way through it.

† From the catalogue of Messrs. W. G. Cannon & Sons, heating engineers, London Road, Southwark, London, S.E.

affect it. The shield plate should be cast iron, which is at all times better able to withstand heat than wrought, when no medium, as water, for abstracting the heat exists. The upper door of this style of furnace fitting is sometimes made circular in shape—an improvement—and sometimes the front casting is also circular at top.

A more modern fitting is as Fig. 105,* a front casting with an arrangement of rails upon which the doors are merely hung, and can be pushed freely to the right or left, or as easily lifted off. This does away with two rather weak features in the other fitting, viz. the hinges and latches, which do not operate well, that is, easily, to the attendant, who more often uses his foot than an instrument to move the doors. This sliding arrangement permits perhaps of more careful adjustment, firstly, of the lower ashpit door, which is utilised as a damper, and of the upper door, which is sometimes opened slightly when the gardener wishes to gradually cool down a little without interfering with his fire. There is also another form of sliding door, which does not project so far as this last one. There has been a set of doors introduced with the outer frame extended so as to include the customary three

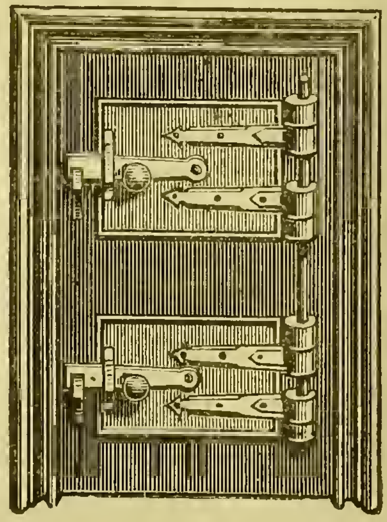

Fig. 104.

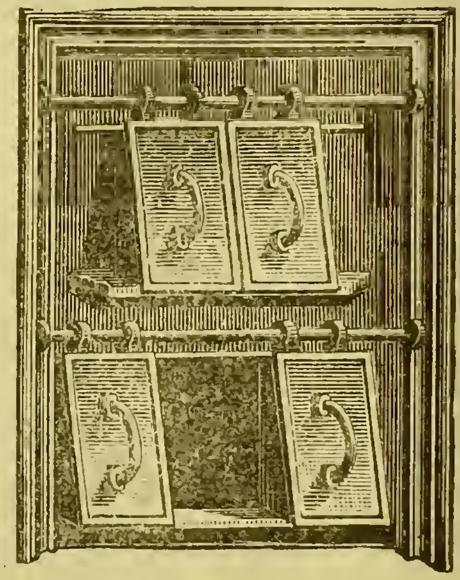

Fig. 105.

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[*] Also from Messrs. Cannon's catalogue.

soot doors in it, as Fig. 106.* This is a decided improvement, as the box soot doors, inserted in the brickwork, will so commonly come lose by friction of the flue cleaning tools; but it must be noted that the provision of soot doors in the front casting rather fixes the positions of the flues.

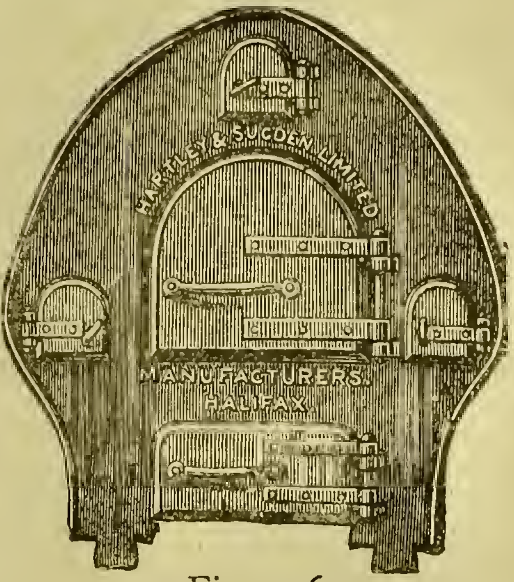

Fig. 106.

The dumb-plate should be of what is called the new or improved pattern, being rebated at the edge where the bars come and rest upon it (see Saddle Boiler). The older pattern was a plain flat plate, which butted against the front edge of the bars, the two being supported by a bearing bar, which was a source of trouble, being situated where a most intense heat could act almost directly upon it. This wrought bar quickly got misshapen.

The furnace bars (which can be spoken of but very briefly, as it is a fit subject for a small book by itself) are very usually of the plain fished or fish-belly shape. These should be thin and deep to give the best service. Their chief enemy is clinker, which adheres most tenaciously, and does its best to stop up the spaces that intervene between the bars. This objection is overcome to a very great extent by using some one of the different pattern bars that are now made with grooves or channels in their top surface, where the fuel rests upon. The usefulness of these grooves is in the fact that they become filled with ash, which protects the metal, and ash being a poor conductor of heat, the life of the bar is lengthened to a considerable extent. This is a valuable improvement, but one which most of the readers will be acquainted with, no doubt. It is by no means new, having been introduced for the furnaces of steam boilers very many years ago.

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* Also from Messrs. Cannon's catalogue.

Water bars, i.e. furnace bars, consisting of a row of tubes having water circulating through them, will be found described under Boilers.

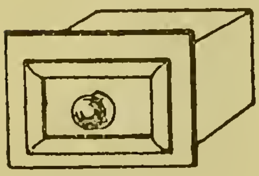

Fig. 107.

The form of soot door most commonly used is as Fig. 107, and is termed a box soot door, by reason of its length. This is the best form of door, the deep flange to the frame giving every facility for its being fixed securely in the brickwork. The damper in the flue needs no description, nor does the form of soot door that requires to be placed in the chimney for sweeping purposes.

CHAPTER IX.

QUANTITIES FOR HORTICULTURAL WORKS.

Hood's rule and its application—Hood's calculating table and notes thereon—Rapid calculating table and notes thereon.

THE quantities mentioned in this chapter are of 4-inch pipe, this being the most useful size, as a foot length can be considered a superficial foot of radiating surface.* The quantities given will therefore readily apply to radiators and other irregular-shaped heating media, the radiating surface of which the makers' lists give in superficial feet. If a smaller sized pipe is used, the quantity used will be one-third more for 3-inch and double the quantity for 2-inch pipe.

Hood has laid down an exact rule which has needed no variation in horticultural work, but which, owing to its complexity, has had little use from the average engineer. But it has been from this rule that most others of a simpler form (but approximate only) have been deduced. The rule is as follows :—

Rule.—Multiply 125 by the difference between the temperature at which the place is purposed to be kept, when at its maximum, and the temperature of the external air. Then divide this product by the difference between the temperature of the pipes and the proposed temperature of the room. The quotient thus obtained, when multiplied by the number of cubic feet of air to be warmed per minute, and this product by 222, will give the number of feet in length of pipe, four inches in diameter, which will produce the desired effect.

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* The circumference of a 4-inch diameter exceeds a foot by a trifle, but not sufficient to require special calculation unless desired. It errs the right way.

This rule is based upon the fact that every superficial foot of glass which constitutes a glass-house is capable of cooling 1¼ cubic foot of warmed air down to the temperature of the air on the outer side of it, per minute,* and the result given by this rule is the quantity of 4-inch pipe needed to make good this cooling influence. The calculation allows for the lowest possible night temperature outside, say 10° F. (22° below freezing), and the water in the pipes being about 180°. In allowing for so low a temperature as 10°, it is supposed that all ventilating appliances will be closed at this time, which would be in the night; ventilation only being allowed on a very small scale during the day, when the thermometer would register 20° at its lowest. In fact, ventilation must be almost dispensed with when these low temperatures are experienced.

According to this rule, a grape-house requiring to be kept at a temperature of 60°, and having 1000 superficial feet of glass to it, would require 293 feet of 4-inch pipe, as follows:—125 × 50 (difference between internal and external temperature) = 6250 ÷ 120 (difference between heat of pipes and internal temperature) = 52 × 1250 (cubic feet of air cooled by 1000 superficial feet of glass per minute) = 65,000 ÷ 222 = 293 feet of 4-inch pipe to keep up a heat of 60° in the house when the outer temperature is 10°.

In arriving at the quantity of glass, the material of the frames, &c., is included; but if they be wood, one-eighth total area can be allowed and deducted. For metal frames no deduction is permissible, as they as readily reduce the temperature as glass.

Hood points out that although wind is a most active element in reducing temperature,† there is no need to take it into consideration, as when an excessive degree of cold is experienced it is rarely, if ever, accompanied by wind. Consequently, when wind in any strength manifests itself, the thermometer will always be moderately high compared with the degree of coldness this rule is based upon.

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* Corrugated or plain sheet iron, when existing, requires to be calculated, and have the same allowance made for it, as glass.

† We can readily judge this by the difference in our feelings on a windy day and a still day, although the thermometer registers the same temperature on each occasion. Air is a good absorber but a poor conductor of heat, and when it is still it does not permit of such a ready escape of heat as when it is moving rapidly past the heated surface.

The rule in question permits of variation if the position in which the house is situated should be very well sheltered, or be in any part of England, or other country, where the temperature does not fall so low as that mentioned. There are other features that might be considered, such as whether the fire will be attended to by a practical man or by an inexperienced person, but for general horticultural works it may be considered that the attendants are experienced.

Hood also points out, and goes to some lengths to prove, that the glass, whether vertical or sloping (for both appear in nearly every glass-house), needs but the same allowance in calculation. There is, as he shows, a difference in the degree at which the heat may be abstracted; but the difference is unimportant, and as it would be governed by a number of complex conditions, it is best to treat all the glass at the same rate. But to be safe, the surface which loses heat the fastest is taken as a standard, and this cools 1¼ cubic foot per superficial foot per minute, as already stated. There is also a difference between lapped glass* and glass set in iron or wood frames; but this difference only exists if the internal air be dry. This is never the case in horticultural work, so no allowance on this score is needed.

As before stated, Hood's rule, though mathematically correct, is, we may say, never used: it is not adapted to the understanding of many who undertake this work, and with those who might be able to use it, something that permits of more rapid calculations being made is better liked, notwithstanding that the rapid calculating tables introduce a deal of approximate and guesswork.* This, however, is usually met by allowing a little more pipe than the needful quantity, if it is considered that the circumstances require it by reason of exposed situation, &c.

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* The majority of new work is carried out in this way, as all the new systems of horticultural glazing allow for lapping one pane upon another, with usually a complete absence of jointing material.

The rapid tables are compiled by allowing a certain quantity of pipe per thousand cubic feet capacity, the quantity of pipe varying with the temperature required, so that if we have a glass-house 30 feet × 10 feet × 10 feet, we readily find its cubical capacity is 3000 feet, and if we require a temperature of 65° when the thermometer registers 10° outside, we must allow 55 feet of 4-inch pipe per 1000 cubic feet capacity = 165 feet of pipe for the house in question. Nothing could be quicker than this, but it is very unreliable, chiefly for the reason that in twenty houses of the same cubic capacity, probably not two would have exactly the same area of glass.† As all authorities agree, the area of glass controls the results in these works, and differences in results must consequently occur. In many cases the variation may not be important, and if it is it will be noticed and allowed for.‡ Another feature making the capacity tables unreliable is that if we have a house, say 20 feet long, and one 40 feet long, both of the same width and height, we get in the second double the cubic capacity of the first; yet (assuming they are both built to the same design) we do not get double the glass surface. We should get double the top and side surfaces, but the ends would remain the same, and as the ends represent a moderately fair proportion of the whole, an inaccuracy of some moment is introduced.*

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* Guesswork is much too prevalent, and doubtless would account for many failures. How many engineers are there who would confess to taking measurements by sight only, without a rule or measuring tape?

† The difference in this respect between lean-to houses (against a wall) and span houses is sometimes considerable.

‡ It is the quantity of glass wholly and solely that regulates the quantity of pipe required in horticultural work: when once the interior is heated the heat may be said to be lost from the glass only. There is practically nothing else to abstract the heat except ventilators, and the gardeners do not look to bring these appliances into use when the weather is at its coldest. At other times the heat given off will permit of a little reduction.

TABLE SHOWING THE QUANTITY OF 4-INCH PIPE THAT WILL HEAT 1000 CUBIC FEET OF AIR PER MINUTE ANY REQUIRED NUMBER OF DEGREES, THE TEMPERATURE OF THE PIPE BEING 200° FAHRENHEIT.

Temperature of External Air.	Temperature at which the place is required to be kept.									
	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
Deg. Fah. 10	126	150	174	200	229	259	292	328	367	409
12	119	142	166	192	220	251	283	318	357	399
14	112	135	159	184	212	242	274	309	347	388
16	105	127	151	176	204	233	265	300	337	378
18	98	120	143	168	195	225	256	290	328	368
20	91	112	135	160	187	216	247	281	318	358
22	83	105	128	152	179	207	238	271	308	347
24	76	97	120	144	170	199	229	262	298	337
26	69	90	112	136	162	190	220	253	288	327
28	61	82	104	128	154	181	211	243	279	317
30	54	75	97	120	145	173	202	234	269	307
32	47	67	89	112	137	164	193	225	259	296
34	40	60	81	104	129	155	184	215	249	286
36	32	52	73	96	120	147	175	206	239	276
38	25	45	66	88	112	138	166	196	230	266
40	18	37	58	80	104	129	157	187	220	255
42	10	30	50	72	95	121	148	178	210	245
44	3	22	42	64	87	112	132	168	200	235
46	..	15	34	56	79	103	130	159	190	225
48	..	7	27	48	70	95	121	150	181	214
50	..	..	19	40	62	86	112	140	171	204
52	..	..	11	32	54	77	103	131	161	194

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* In the same way a glass conservatory, which is very commonly higher than a vinery, would get more than its proper share of pipe (which, however, is no fault), as, supposing it to be double the height of a green-house, it would have practically the cubic area and side glass surfaces of two green-houses, yet it would only have one top.

Hood, in his painstaking way, went to great trouble to compile a table that would dispense very greatly with the complexity of the calculations needed by the rule he first laid down, this table being based upon the rule itself, but, as it will be seen, making the total to be arrived at much more easily discovered. This table, however, has one serious objection—viz. that it is based upon the pipe being at a temperature of 200°. Although this heat is quite possible, it is not usually experienced in effect, and 180° should be considered the maximum* with skilled attention. Therefore, if it is desired to make use of this table, one-fifth should be added to the quantities of pipe given to allow for the pipe temperature being 20° lower than that which Hood has calculated upon.

It was mentioned that the glass was the sole cause of loss of heat in horticultural work after the interior air and fixtures were once heated. This is so; but in the usual way it takes some hours to get the heat up to the required degree when first lighting, as, firstly, there is the volume of air to be warmed, then all the interior fittings are absorbing heat on a considerable scale; and what takes even longer to cope with is the amount of moisture that would exist in such an instance and neutralise the general effect of the heat in a great measure. A perfectly dry place would be heated up more quickly.

Hood approximated the time that a glass-house, with a sufficiency of pipe, and a boiler of corresponding power, takes to become heated up as follows:—

With 4-inch pipe	about 4½ hours.
„ 3 „ „	„ 3¼ „
„ 2 „ „ †	„ 2¼ „

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[*] The word "maximum" is correctly used, for unless the fire receives proper and sufficient attention from a person accustomed to the work, 180° will be the exception and not the rule.

[†] The results with 2-inch pipe are so much quicker, as they contain much less water for a given amount of radiating surface than the larger sizes.

These times cannot be relied upon with any accuracy, although they are useful to base an idea upon. In first heating up, the time must vary by the condition of the interior and its fittings, whether very damp; the cubic contents compared to the area of glass; and the natural temperature of the atmosphere, which varies still more. When the fire is started, the warmth from the pipes goes to heat the air, and the air to heat what it first comes in contact with, and for a little time the glass has no cooling influence. But as soon as the whole internal air has attained a higher temperature than that outside, then the cooling process is commenced, and it increases as the heat inside is increased, until (supposing the quantity of pipe to be exactly correct) they balance one another.

In the following rule for calculating quantities of pipe per 1000 feet cubic contents of glass-houses, it must be repeated that the figures are approximate only, conditions and position varying. The pipe is supposed to be kept at 180°, and the extreme coldness of the outer air to be 10°.* In the inspection of a green-house the following things require consideration before fixing the quantity of pipe.

1. Its position, whether exposed, or sheltered by surrounding houses, trees, or walls. If exposed, additional pipe should be used. (Span houses suffer most in this respect.†)

2. Position with a lean-to house, as to whether it faces south, south-west (the two best), or a more trying quarter. If not south or south-west, some additional pipe should be allowed.

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* This can only be for a limited number of nights in winter. Some fruits require a varying heat, as tomatoes, which, when being ripened off, are commonly given a higher than normal temperature. Unusual heats are never needed in mid-winter, and at other times nature will assist. A maximum temperature of say 70° in winter can readily be increased to 80° in spring.

† Span houses are commonly lower (taking a mean height) than lean-to houses, and consequently have more cooling surface for the cubical capacity than they would have if they were as high as the other houses. A cube-shaped house would give us the least glass surface in proportion to its internal capacity; any deviation from this increases the cooling surface.

3. If not a large works, it is important to know how the fire will be attended to. If by a coachman or boy, then extra pipe should be allowed (and a little larger boiler would be advisable).

TABLE.

The following table shows the length of a 4-inch pipe needed to keep up a given temperature to every 1000 cubic feet capacity in a glass-house for horticultural purposes, the pipe being at 180°, and the outer air at 10° or higher (no ventilation when outer air below freezing point).

Temperature required.	Quantity of 4 in. pipe to each 1000 cubic feet capacity.	Some of the purposes for which the houses may be required.
Deg. Fahr.	feet.	
90	80	Pines and forcing purposes.
85	75	
80	70	
75	65	Tropical flowers and some ferns.
70	60	Pits for melons, &c.
65	55	Grapes, strawberries, tomatoes.
60	50	
55	45	
50	40	Fruit trees, conservatories.
45	37	
40	35	Trees, cuttings, stock, &c.

For 3-inch pipes add one-third to the above quantities. For 2-inch pipes double the quantity.

The above quantities are for lean-to houses, with one side of brickwork. If span houses (position not much exposed) add one-fifth to the lengths of pipe given.

Whatever pipes are carried in trenches or channels covered with a grating, must be calculated as being one-fifth less effective than those that are exposed.*

Notwithstanding every care being used in compiling the above Table (which, with a gardener's attention, will be found safe and give the results quoted), it is better to allow a little more pipe if there is a doubt about the fire being carefully tended.* Even 15 per cent. more pipe could advantageously be used in such a case, as the greater quantity admits of less frequent attention at the furnace and further obviating risk of failure. It must be remembered that for the heat to go down on one occasion only is sufficient to cause disastrous results if the weather be severe.

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* If the channels are not of full size the pipe will be still less effective.

The remarks in the right-hand column of this table are, to a great extent, useless, as it must not be supposed the hot-water engineer is the person to fix the temperature for certain purposes. It is understood he has to receive instructions in this respect from the gardener.

Notwithstanding the use of this rule, it can be recommended as a wise precaution that the area of glass be also measured as accurately as possible, and the amount of pipe required calculated by Hood's table, and so let one method check the other. This will, it is to be hoped, bring the result as close to accuracy as it is possible, for should the two calculations differ to a serious extent, it will at once indicate the existence of some unusual circumstance in construction. This may be considered unnecessary, but it is trouble worth taking. Nearly every one has heard of failures occurring in hot-water works of this kind. They are not infrequent, but in nearly all such failures the apparatus will be found correctly erected but insufficiently effective, the calculations having been wrong somewhere, either in boiler or pipes, or both. It will not be forgotten to allow upon Hood's table, as explained just before it.

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* No such allowance is necessary if the works are for a professional grower or an amateur on a large scale, as there would be skilled attendants employed.

CHAPTER X.

FUEL, STOKING, AND ATTENTION TO HORTICULTURAL WORKS.

Fuel—Steam coal, coke, &c., and its use—Sulphur—Stoking and regulation of the fire—Damping down—Attention to air vents—Flue cleaning—Frost, and precautions necessary—Non-freezing solution—Clean surfaces to ensure full radiation of heat.

It is desirable, perhaps, before closing the description of horticultural hot-water works, to mention a few things in connection with the use of the apparatus, as to stoking, &c.; also as to some different features in these undertakings that require attention after the work is complete.

The fuel used in these boilers* is almost as varied as fuels can be, as in many places, badly situated for conveniently obtaining what may be best suited, recourse has to be had to wood and even peat, when coal or coke runs short, or the latter is difficult to obtain. In fact, anything that evolves heat will do temporarily if the apparatus is not on a large scale; but with such fuel as wood, much more attention would be needed. Wood in blocks, made by cutting about a 6-inch tree branch into 6-inch lengths, will be found fairly successful when nothing better can be obtained at the moment required.

The customary fuel for very large boilers, brick set, is hard steam coal. This coal has a moderate percentage of bituminous properties, sufficient to cause a useful and effective amount of flame without making such a heavy deposit of soot as the softer kinds of coal do. The latter commence to flare before they are at a really intense heat, the soot not

* For both horticultural and building works.

only preventing the water having the benefit of the heat evolved, by its low conductivity,* but also represents so much lost fuel—fuel converted into a form in which it cannot be usefully employed for giving heat. The steam coal, although having a flame and causing a soot deposit, has not this latter disadvantage in nearly such an aggravated form as the soft coal. In the first place, its bituminous properties are limited ; and, secondly, in burning it reaches a much higher temperature and state of incandescence than the other, which greatly aids in reducing the formation of soot.

This coal is not expensive, from 16*s*. to 19*s*. per ton delivered in London in one or two-ton lots (small quantities), and it is very economical in use, it being so lasting in combustion; but it is not so inexpensive as what is known as slack, which is coal-pickers' refuse, not necessarily small, but very mixed usually, and costing practically nothing but cost of transit from the pit. Slack is not so good in general results as hard steam, and not so clean, but some people minimise its drawbacks to some extent by mixing coke with it. A mixture of coal and coke is a very effective fuel.

For medium-sized brick set, and for independent boilers of practically every kind, coke without any coal admixed is nearly always used, more so than any other fuel. Coke, when fairly alight, evolves a most intense heat, as it so readily becomes incandescent, and there are then no obstacles whatever (smoke and soot being absent) to the boiler experiencing its full effectiveness. No doubt the absence of soot is a great factor in the good results obtained, as the surfaces, particularly in the flues, are kept so clean, and it will be found that the heated air and hot gases from a coke fire do excellent work outside a boiler. Not so much as flame at first starting perhaps, but flame, by the soot it carries, so soon neutralises its capabilities to some extent.

Coke, however, is said to have rather a deleterious effect upon ironwork by reason of the action of the sulphur contained in it. This sulphur is, of course, present in coal even to a greater extent than with coke, as in the conversion of coal to coke a deal of sulphur is carried off with the gas; but it will be found that in the consumption of coal the sulphur is not nearly so noticeable, as different causes tend to render it more inactive. The activity of the sulphur with coke is, however, not very objectionable upon surfaces which are kept at a low temperature by water being in contact with them on the other side, and the present forms of welded wrought boilers and cast boilers, which have all smooth surfaces, suffer very little indeed. This cannot be said with furnace fittings or with any projecting parts from a boiler itself, and with riveted boilers it is generally considered that the ultimate failure of the rivet heads on the heating surfaces is due to the insidious action of the sulphurous acid when coke is used. With coal fuel, the rivet heads do not suffer nearly so much, although the coal may have a greater percentage of sulphur in it than the coke.

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* Were it possible, soot would be fairly effective to put outside independent boilers to prevent loss of heat, as it ranks moderately high as a low conductor.

Notwithstanding the sulphur, coke is the best fuel for nearly all boilers, and it is of particular advantage with those boilers which have a complexity of tubes or irregular heating surfaces, and which would be of some trouble to keep clean of soot. With the small forms of independent boiler, all the cinders from the house fires can be successfully used.

Another fuel specially well adapted for medium and small sized boilers (or any size boiler of the independent kind) is Anthracite Coal. This can be as easily obtained as ordinary coal, and more easily than coke in many cases. The difficulty seems to be in getting this coal of a proper quality or kind, as it varies much from different pits. The American anthracite is considered to be excellent for this purpose, yet more than one American engineer in England has spoken of the anthracite obtained from a Welsh mine as being better than theirs. Some coals of this variety, in addition to being of poor quality, decrepitate as they get hot. The pieces split and fall into small fragments, too small to admit of combustion occurring properly. A good anthracite is decidedly superior to coke, being quite smokeless of course, gives off no objectionable volume of sulphurous acid, and burns in a peculiarly steady and satisfactory way, evolving great heat. It is also a very clean fuel, making little ash or débris.

Much skill can be shown in stoking a furnace, even with those of a small size, and with those of large capacity it is well known that stoking is a calling in itself, needing experience. With boilers for ordinary hot-water works, however, it is only necessary to point out a few rules for general observance.

The most effective fire, that is, the one to give the greatest results with the least expenditure of fuel, is that which is always kept bright, and this can only be done by frequent and regular attention. It is necessary with this object in view to keep a rather thin layer of fuel upon the furnace bars (except when banking up for the night), as apart from the brightness of the whole of the fuel, the combustion is rendered more perfect with less formation of carbonic oxide (see Combustion). With coal fuel it is the custom to make use of the dead plate immediately inside the furnace door for receiving a charge of fuel, so that it may be dried and partially coked, the more volatile products being thrown off as it lies at this point. These products having to pass across the incandescent fuel, undergo combustion, and do effective work instead of going to form soot, as they would have done if the coal was put directly upon the fire. It is very improper to force fires, that is, get them up to a fierce state in a short time ; it should be quite unnecessary, and is commonly evidence of bad stoking. This frequently happens with a new apparatus in a building, where the attendant is an odd man not having sufficient skill and being unacquainted with the work, the consequence being that the water becomes overheated. Unless the boiler has an expansion pipe directly from it, and this of good size, there will then be an overflow at the supply cistern by the generation of steam in the boiler. When this occurs it is most quickly stopped by opening the front furnace door, which will permit of a free passage of cold air *over* the fire to the flue; the boiler will thus be cooled, and the effect of the fire lessened.

If the boiler is fully large for the work the risk of overheating is increased, but this risk can only be for the first few days, as the attendant should quickly become acquainted with the use of the dampers. The advantages of the larger boiler then become apparent, for with the greater effectiveness of the large fire, the dampers can be nearly closed, and attention in feeding the fire reduced to a minimum. In the end it will be found that a saving of fuel is effected by reason of the lessened draught and speed of combustion, although the boiler takes a larger charge of fuel in the first place. It is the common practice for gardeners to use the front furnace door to lessen the heat, instead of altering the damper in the chimney.

In charging the boiler with fuel for the night, it is usual and best to place some ash on top to "damp" the fire down as it is termed, the real effect of the ash being to choke the air passages between the fuel, and smother it to an extent. A fire skilfully "damped" down will keep alight for an incredible time, but it is only for the night that this practice is adopted, as it causes the fire to get into a dirty state, and less effective, unless it is raked and cleaned as requires to be done each morning. This latter attention does not necessitate withdrawing the active fuel from the furnace.

In an apparatus having air-cocks instead of the usual open air pipes, it is very necessary that these be opened to discharge the air frequently. It will be found that air accumulates at the high points in the apparatus (of any kind) very rapidly, and it is a good plan to open the air-cocks as often as twice a month, as in many instances the accumulation of air may be at a point where a small quantity will interfere with or wholly check the circulation.*

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* A peculiar instance of this came to the writer's notice quite recently: a school dining hall insufficiently heated by the fires was fitted with some radiators in connection with a hot-water apparatus. They were a success for a week or two and then failed, and the master, instead of mentioning

The time for cleaning the flues varies from several causes, but experience quickly fixes the time in which it should be done, as the attendant can so readily judge by the quantity of soot or dirt that he removes. Attendants' ideas, however, vary, as those who have the time and the desire clean the flues very frequently—daily, as it renders the boiler more effective, and is consequently a good practice. With coke fires, attention in cleaning is still needed, but not with such frequency as when soot is formed. The deposit from coke is a fine dust, which will be found in the greatest quantity on horizontal surfaces, or anywhere that it can rest.

Frost has carefully to be guarded against in all hot-water works, but more particularly in those devoted to horticulture. There ought not, however, to be any fear that frost will be permitted to act upon the contents of a glass-house unless the attendant be exceedingly careless, but there are other effects of frost that need be thought of.

If a new apparatus be completed during severe weather, it should not be charged and left full of water unless it is convenient to light the fire at once, and to keep it alight night and day. In the same way no existing apparatus should have the fire drawn, and be allowed to cool down, unless it is intended to at once withdraw all the water it contains, for should the water in the pipes, radiators, or any other parts be allowed to freeze, considerable damage will be caused.

It is unnecessary to deal with the question of the expansion that takes place when water freezes. This, in a general way, is within every one's knowledge, and it is sufficient to point out that no cast or wrought-iron pipes, used in a hot water apparatus, are strong enough to withstand it. A fracture must occur, unless by some favourable circumstance there is a space into which the water can expand itself with-

the matter, took it for granted that the work was a failure, and actually let the matter rest for nearly two years, when it was discovered that the air taps had never been opened, and the radiators had been full of air all this time. No water could get into them to be of use, as they had upright pipes, which necessitates their being quite full to permit the water to circulate.

out resistance. Sometimes an expansion joint of one of the many kinds will prevent damage, as the force exerted will disjoint the pipe, but this cannot be relied upon by any means, for the expansion is very sudden. The smaller the pipe the quicker the water freezes, and the only really good remedy is to keep the fire alight or to empty the apparatus.

There are now to be obtained materials that will successfully prevent water freezing at the lowest English temperature. Mr. Stainton* patented a solution containing as its chief ingredient chloride of calcium, and this permits of water retaining its fluidity at an intense degree of cold. Common salt is effective in a sense, as water will take sufficient in solution (about 30 per cent.) to prevent it freezing at our lowest winter temperatures. There are, however, reasons for its not gaining in favour, and it cannot be recommended.

It requires to be mentioned that if a boiler and apparatus be emptied, great care must be exercised to see that it is properly recharged before the fire is lighted. Not only would injury be done to the boiler, but the inflow of water on to the hot boiler plates is not an experience to be courted, even if nothing serious happens.

It is also necessary to protect air pipes from frost. They should always be disposed so that the part of the pipe that contains water is within the house, only the empty portion, if any, passing outside. It is not always that air pipes are carried outside at all, except to avoid injury by steam or ejected hot water should the boiler be over-fired.

All pipes and radiating surfaces must be kept clean and free from dust. Dust is composed chiefly of materials that are poor conductors of heat, such as silica, cotton, wool, wood, straw, &c., all of which act well as barriers to heat distribution. Pipes in trenches and beneath gratings are apt to be neglected and do very little effective work when in a dirty condition.

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* Of the firm of W. Stainton and Sons. His invention was for the object of preventing the water being frozen in the pipes of high-pressure apparatus, which cannot be so readily emptied and refilled, certainly not by an inexperienced person. For this purpose the invention is a decidedly valuable one.

Every portion of pipe, whether of mains or branches, that is not used for heat distribution should be covered with a material or protected in some way to prevent loss of heat. Heat diffused where not required is clearly a waste of fuel, involving extra labour and fuel, also impairing efficacy. Heat wasted in this way should be particularly objectionable to an engineer, as it is decidedly bad in practice. This subject has already been referred to.

This practically completes the horticultural section of this treatise, except for the boilers, which are treated in the next chapter. As similar boilers are used for both brick buildings and glass-house works the chapter can be considered to apply to both branches of the subject. The pages devoted to boilers divide the horticultural from the buildings section of the book.

CHAPTER XI.

BOILERS.[*]

Heating surface, direct and indirect—Horizontal and vertical—Different resulting effects due to different conditions of the fuel — Hood's standard of heating surface areas and its application—Boiler-makers' lists, and the deduction necessary to be made from them—Flue surface and its value—Action of flames and heated gases in flues—Fletcher's heat collectors—Suggested new standard value of different heating surfaces—Small and large waterways—Deposit, its effect and removal—Cast and wrought boilers—Area of furnace bars—Hood's table, and necessary additions thereto.

THE last chapter practically closed the section of the book which relates to horticultural heating works, as the present one, on Boilers, applies to all descriptions of hot water systems alike. There are, we may say, no boilers that exclusively belong to either glass or brick building works. Some are used more regularly for one purpose than the other, but not to such an extent as to make their division necessary or desirable. The subject of boilers is therefore treated in this chapter to divide the two somewhat diverse subjects of heating glass-houses, and affording warmth to the totally different kind of houses that are constructed of brickwork.

It is only possible within the limits of this chapter to deal with a representative selection of boilers, showing some of the leading features, and illustrating the peculiarities of those that have gained public favour and for which there is a fairly general demand.

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[*] This chapter is devoted to an explanation of all those details which affect the general efficacy of boilers of all kinds. It also particularly deals with the heat values of different surfaces in boilers, that actual working figures may be calculated instead of the theoretical or approximate figures used in the past. Descriptions of Independent and Brick-set Boilers will be found in the chapters following this.

Before proceeding with the actual description of the various boilers, it is necessary to refer to some of the special features that an effective boiler should possess, and also to review Hood's decisions in this direction. The first question to be considered is what qualities constitute a good boiler, that is an efficient boiler, one that gives the best results for a given size or space occupied, working under normal conditions and without undue expenditure of fuel, labour, &c.

One would be led to think that this question had never yet been satisfactorily answered, judging by the number of different boilers that have been designed from time to time. Even now new forms are continually being introduced at fairly regular periods, but it is evident that the old pattern "saddle" boiler still retains favour. Large numbers of these are at this moment being made and used—quite ten times as many as any other shape, and nearly every new design bears some resemblance to the old saddle form. Therefore, for the study of what constitutes a good boiler we may take the saddle, Fig. 108, as an example.

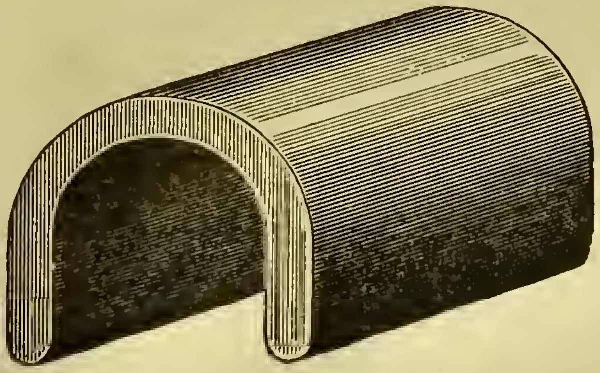

Fig. 108.

It can be readily understood that the boiler surface immediately facing the fire, or in direct contact with the glowing fuel, is at the greatest advantage in heat absorption. Particularly is this so with that part of the boiler which comes directly over the fire, for with a mass of fuel confined to a certain space, as it is in a boiler, it will be found that a great effect is made by the heat that is radiated from the top of the fire, assuming the fuel to be in an incandescent state. In any case it may be accepted as a recognised fact and rule that the part of the boiler directly facing or in contact with the fuel, absorbs heat at a much greater speed than any flue surface, in a proportion that will be determined directly.

As a rule it is understood that the area of boiler surface immediately over the fire is of greater value than that which forms the sides or bounds the fire, in a proportion of about three to two. Hood has fixed the ratio at this, and theoretically it may be accepted, though not strictly exact. It is, however, desirable (to prevent an error being fallen into here, for these results are only based upon the supposition that the fire is in a similar state of combustion at sides and at top) to adopt a more simple way of arriving at the conclusion. Let us suppose that we have a vessel of water, a kettle, which has a side surface of the same area as the bottom (a cube for instance); also let it be supposed that we have a fire in an incandescent state, with the top surface and the front surface in an equally glowing state. Now if we boil the water by placing the vessel on top, we shall get the result aimed at in a much less time than if we put the side of the vessel against the front of the fire. This is what it is intended to convey when we read that the boiler surface *over* the fire is of a greater value than that which bounds or comes opposite the side of the fire, and it will be seen where an error is made, viz. in assuming the top of the fire to be always in a glowing state.

If the attendant is skilled as a stoker, and if he take the trouble to stoke the fire regularly by use of the dumb-plate, then each charge of fuel is prepared before it is put upon the active part of the fire, and its bright and glowing state is little interfered with. But this is an assumed state of things, for unless the apparatus is on a large scale, necessitating the almost constant employment of a fireman, there is very little skilled stoking done. Neither is it expected nowadays, for in most of the new boilers introduced a feature is made of economising time in stoking, so that the fire can be charged and need no attention for several hours. This gives opportunity for other useful work to be done in the time that might otherwise have been spent in stoking. It will also be understood that during the night, with any description of boiler, the fire has to be made up and cannot have constant attention, and at night (with horticultural works) the greatest heat is needed.

The object of this explanation is to show that only under rather special and favourable circumstances is the *top* surface of the fire in a bright and glowing condition. And to arrive at the theoretical power of a boiler we must not be too ready to give a much higher value to the surface over the fire as against the surfaces at the sides of the fire, especially as the latter have actual *contact* with the fuel, which the former has not. Again referring to the kettle illustration, we can see that if the front of the fire was of red-hot fuel, and the top of the fire was black with fuel newly put on, it is just possible that the kettle placed in front would heat the more quickly. Under these circumstances the boiler surface immediately around the fire, whether at the sides or above, should be estimated to give about equal results in the aggregate.

In every description of boiler, whether new or old, there is one important feature that has to be studied in judging its effectiveness. This is, whether it has every possible portion of its surface area devoted to direct or primary heating, that is, surface coming directly opposite the fire. Should any portion of this surface be sacrificed to make flues, then unless the flue surface so gained is three or four times as large as the direcheating surface sacrificed, the results will be lessened and not increased. Boilers have, and may have, flues by all means, but flue surface being of so much less value than direct heating surface (in a proportion that will be directly investigated) it has never been found advantageous to lessen the latter for the purpose of increasing the flue room.

This undoubtedly accounts for the favour that the saddle boiler has so long enjoyed, its shape making it so capable of benefiting by the heat, forming as it does an envelope to the fire, and conducing to a freer circulation than we get from a flat top. Hood points out the advantage gained by the use of an old pattern boiler (which existed some years ago but is no longer to be found) which much resembled a large basin inverted over a fire, and having a flow pipe proceeding from the apex. With this very excellent results were obtained, but it could not conveniently have flues carried about it, and was not suited for any large purposes. It serves, however, to illustrate the advantage of direct heating surface.

We have now, however, boilers that bound the fire on all sides, as the one just described did, but not necessarily circular, and they have the advantage of being adapted for flues to be carried around them (so as to heat the outside surface as well as the inside), as will be explained directly. One is the saddle boiler, but with water-way front and back ends, Fig. 109; another is a circular boiler, Fig. 110, which bears several names and will be described in a later page. There are also some other designs that fulfil this object; in fact, makers are generally alive to the importance of getting the utmost direct heating surface, and making boilers to envelope the fire so as to benefit by the radiant heat and fuel contact to the utmost extent. Flue surface is nearly always easy of attainment, but is of comparatively little value at the best, except that part where the flame has impact immediately it leaves the fire. The tail of the flame and heated products, after having travelled the length of the boiler once, do but a very limited amount of work. (See Flame Contact, p. 187.)

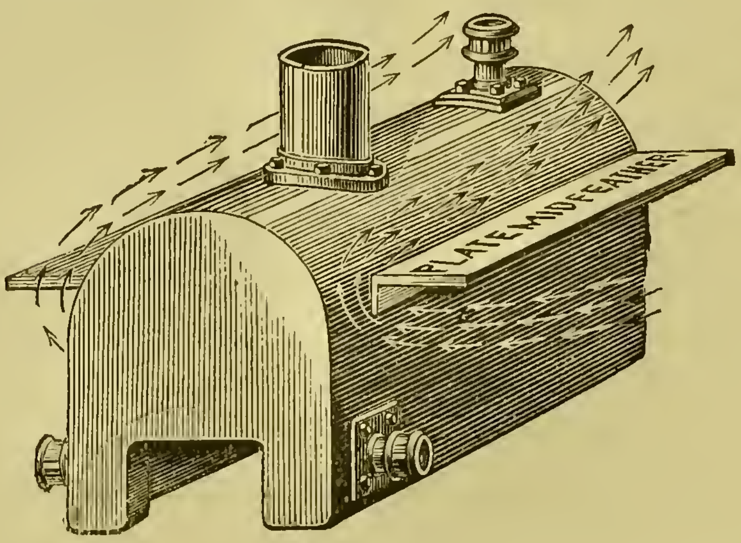

Fig. 109.

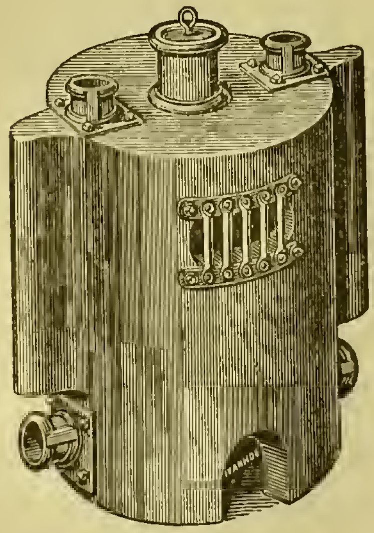

Fig. 110.

This now brings us to consider and discuss one of the most important features in Hood's book, and which is brought to the notice of every engineer when purchasing boilers for hot-water work. This is the question as to what area of heating surface a boiler should have, to render a certain amount of service. In other words, what amount of pipe or radiating surface can be effectually worked from a superficial (square) foot of boiler surface.

Hood, in his painstaking manner, went to great trouble and apparently took note of many results before arriving at and fixing his data, and to the best of every one's judgment, he succeeded in getting accurate figures. But, unfortunately, these figures were arrived at under the most favoured conditions as to surroundings, construction, quality of fuel, good stoking, external temperature, &c. This is much to be regretted, as practically every boiler maker has adopted his standard, with very unfortunate results.

The standard which he set up, was that one square foot of boiler surface, subject to a direct heat, was capable of heating 50 feet of 4-inch pipe. If any flue or indirect heating surface entered into the calculation then three times the area was to be allowed, that is three square feet of indirect heating surface was to be allowed for 50 feet of 4-inch pipe. This was the standard adopted by the majority of boiler makers, but they are not free from fault in adopting it, as Hood clearly points out the favourable circumstances ; and strange to say, the boiler makers have overlooked an important paragraph affecting this matter, in which Hood says, " A very good proportion, suitable for nearly every purpose, is to allow about one foot of boiler surface (direct heating) to about 40 superficial feet * of pipe or other radiating surface, or about one-fifth more boiler surface than the preceding Table states."

* The word " superficial " is correctly used, as the circumference of a 4-inch pipe is so nearly 12 inches ; every foot in length of this sized pipe may be called a superficial foot in this work. Of course a foot length of this pipe exceeds a superficial foot, but only so little as to make special calculation and allowance unnecessary. The figures err towards efficacy, not against it.

This very clearly shows Hood's feeling in the matter, viz. his disbelief in his original standard acting up to the results given if worked under common conditions, which differ so greatly from the conditions that attend an experiment. But, as before mentioned, this last paragraph and the detail leading up to it have been quite ignored by those who have adopted his data and hold him responsible for their figures.

Of course the makers and users of boilers quickly became aware of the unsatisfactory results that attended the adoption of this standard when the boilers were put to work, for the way that many boilers are used shows a great desire to economise labour to the prejudice of good results. A method of obviating this difficulty had therefore to be discovered, and the general rule adopted was to adhere to Hood's data, but with a brief preface as follows :—

"The heating powers given in this price list of boilers are based on Hood's standard work on hot-water heating, viz. 50 feet of 4-inch pipe for each foot of direct heating surface in boiler, and one-third this quantity for indirect or flue surface ; but for ordinary actual work the heating powers in the list should be reduced 30 per cent., thus a boiler estimated to heat 1000 feet should only be put to 700 feet to do its work well and economically."

The standard list that this refers to is as follows :—

Wrought Welded PLAIN SADDLE BOILERS,
with from 2-inch to 3-inch Waterways, according to size.

L.		W.		H.	Approx. Heating Power, 4-inch Pipe.
24	×	12	×	12	300 feet.
30	×	14	×	14	425 „
36	×	16	×	16	600 „
42	×	18	×	18	800 „
48	×	21	×	21	1000 „
54	×	24	×	21	1300 „
60	×	24	×	21	1500 „

This list is abbreviated for sake of space. There are many intermediate and some smaller sizes, and of course there are many other lists that apply to other forms of boilers, but all calculated results are based upon Hood's original data, which require the deduction of fully 30 per cent. to arrive at actual practical value under ordinary conditions.

In actual practice, especially if first cost is not of great importance, it is desirable to make even a greater deduction than this, so as to permit of economy in stoking and attention; also to provide for the advent of any unusual condition, in weather, surroundings, or attention, that may occasionally manifest itself. This greater deduction from the standard list particularly applies to boilers that have a top feeder as it is termed, like Fig. 111. This boiler is arranged particularly for charging from the top and not from the front, consequently the valuable upper surface of the fire is not usually in a bright state. This arrangement very readily permits of putting a heavy charge of fuel in at one time, and thus less attention is required.

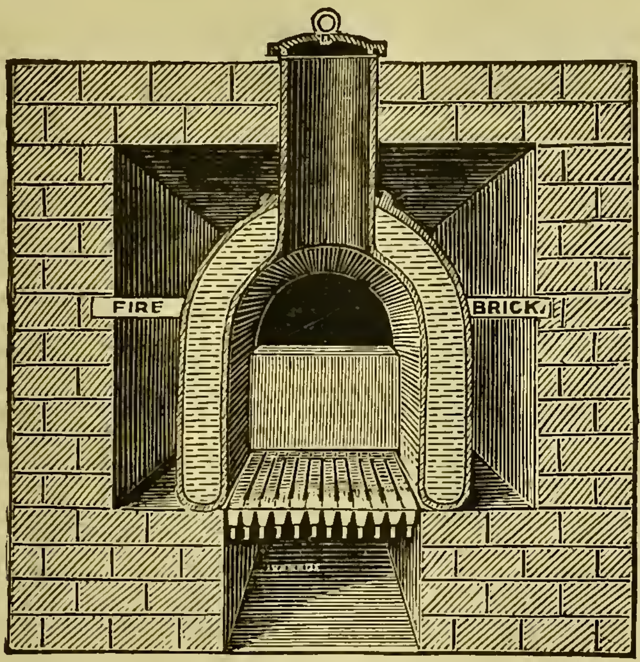

Fig. 111.

Another question to be discussed respecting the standard set up, is as to the value of flue surface relative to that surface which comes next to the fire and is heated direct. Hood has fixed this at one-third, or three superficial feet of flue surface, to give the same results as one foot of direct heating surface. Here again there is a regrettable difference between experimental and practical results, and again is it necessary to hold the heating surface at a lower value than the proportion set down. In the first place, it must be noticed that with the majority of boilers (the saddle shape as an instance) no flue surface can be had *beneath* the water space, the flues having necessarily to be carried along the outer sides and across the top of the boiler. It has already been shown what a much lower value vertical or side-heating surface has, compared with horizontal flat surface with the source of heat beneath it (the condition of the fire or flame being equal in each case), and the value that can be given to heating surface that is beneath the source of heat (as it is when any flue is carried over the top of a boiler) is practically *nil.* It is of no use whatever, or at least bearing only the most trifling comparison to the direct heating surface that we get in the fire-box.

It has also to be considered that flue surfaces quickly get dirty when coal fuel is used, and even when nothing but coke is burnt there is a deposit of dirt on flat surfaces, such as the top of the boiler. Whether the dirt be soot or ash, it requires but a thin coat to materially obstruct the absorption of heat, as the dirt deposited in flues is always of a low conductive power. This goes to lessen the value of flue surface unless the flues are swept daily, which is unusual. Lastly, there is a phenomenon exhibited by flame and heated gaseous products that has been but little understood or noticed.

In the first place, any one having had experience with flues of any description will have noticed that flames and other heated products exhibit a strong disinclination to come in contact with surfaces of any description. Should the flues be too large, the flame and gases in their passage from the fire to the chimney will not do so much useful work as they might do otherwise. The objectionable feature in this is that the flame gives off but little heat by radiation, and may be said to heat by contact only, consequently the flues should be sufficiently small to bring about this result; at the same time not so small as to become quickly stopped by soot, or to choke the draught. Flues to a furnace burning coke only may be a trifle smaller than those connected with a coal fire, but this will be dealt with in its proper place.

The next question affecting the comparative value of flue surface, is a somewhat peculiar one, involving the discussion of a phenomenon that Thomas Fletcher, the well-known gas engineer, treated in a paper read before the meeting of the Gas Institute, London, June 9th, 1886, entitled, "Flame Contact: a new departure in water heating." This is the fact that flames under ordinary conditions do not come in contact with a vessel containing water at all. Whether the water is hot or cold, or whatever the vessel be made of, there will exist a thin film of air or space between the flame and the vessel so long as the vessel contains water, or, in other words, so long as the metal of the vessel is prevented from reaching a higher temperature than about 212°. This film or stratum of air does not exist when the flame is acting upon some surface that is at a much higher temperature, it only manifests itself when some cooling influence exists, as the presence of water, which even at boiling point seems to have the repelling effect upon flame as explained. This peculiar action was fully explained by Fletcher in the paper referred to, and it goes to show that, as applied to water heating, ordinary flue surface is still further at a discount.

It is worthy of note that the remedy that Fletcher suggests for this state of things takes the form of a suggestion made by Hood, but the peculiarity is that the two suggestions, although they would bring about the same results, originate from different ideas. Hood's proposition was the addition of gills or projecting flanges outside and beneath the boiler, as Fig. 112, with the view of increasing the area of the heating surface to this extent. From results obtained at that time, it was decided that water covering a certain area of boiler surface was capable of taking up or absorbing heat 2·6 times as fast as it could be received by the same given area from the fire, and the addition of these flanges provided this extra heat-receiving

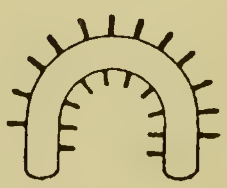
Fig. 112.

surface without any trouble being taken to increase the water surface. This was exceedingly successful with cast boilers, but its application to wrought boilers has never been successfully carried out, although it is worthy of serious attention from boiler makers.* It would not be necessary to adopt gills in particular; any mode of adding to the heat-collecting surface will do, but it should consist of solid parts, for the reasons that will be made clear from Fletcher's investigations.

When Fletcher discovered that a metal surface at 212°, or less, practically repelled flame from contact with it (under ordinary conditions) he set to work to devise a means of obviating what in his mind was an objectionable feature, and opposed to the best results. His experiments showed him that a metal surface which could be raised to a higher temperature readily received flame contact, so he devised a vessel having a large number of solid projections upon the bottom, as Fig. 113, and the difference in results in transference of heat from the flame to the water was very successful. In a small vessel of the ordinary character with a flat bottom, 40 ounces of water was boiled in three minutes fifty seconds, whereas with a similar sized vessel, but with the solid studs or rods on the bottom, 40 ounces of water was boiled over the same flame in one minute fifty seconds. It will be seen from this that solid projections (whether studs or plates) from a boiler have the important advantage of adding to the heat-receiving surface, whether direct or from flame, as aimed at by Hood; and secondly, they have the very important advantage of achieving the excellent results of securing the actual, the utmost real benefit of flame contact.

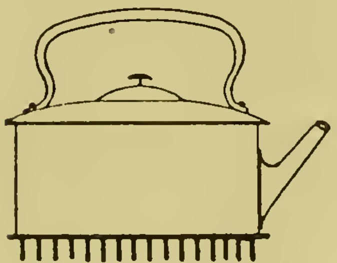

Fig. 113.

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* Corrugated boilers have been introduced for the generation of steam, but these increase the water surface as well as the heat-receiving surface, which is not necessary. But with steam boilers the corrugations are an element of safety, if undue pressure is exerted, as they give to the strain instead of bursting.

This latter feature not only applies to flame but to heated gases (products of combustion, &c.) also; and it is effectual when coke fuel is used, from which we get no flame except the small blue flames from carbonic monoxide. It will be understood that the success lies in the fact that the extremity of the rods or studs (which in this case were 1½ inch long) are too far removed from the water to have their temperature kept down to anything like as low as 212° (after having once become heated); yet by the rapid power of conduction possessed by iron or copper, they are all the time transferring heat from their highly heated extremities to the interior of the vessel.

This brings us to consider whether the flue or indirect heating surface that we obtain with an ordinary saddle boiler fixed in an ordinary way is really of the value commonly put for it, viz. three superficial feet for 50 feet of 4-inch pipe; in the writer's opinion the actual value is much lower.

If a new standard be adopted* it should, for ordinary purposes, be as on the following page. This table of heat values is applicable to boilers of all shapes and makes.

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* In the first new edition of this book it was mentioned how impossible a new standard seemed, as the boiler-makers, unless acting in concert, would have their interests prejudiced. One maker's price list would be, apparently, higher than another's, as a saddle boiler of 500 feet theoretical or approximate power, priced at £5 7*s.* 6*d.*, would have to bear comparison with one of 500 feet actual power at about £7 10*s.* To many who were not accustomed to these price lists, the difference in cost would lead them to purchase what appeared to be the least expensive. Still a new standard was highly essential, for the lists as they stood were really vexatious, to say the least. Consequently several makers have, since the publication of the first edition, issued new lists, and in the introductions appearing in them, state that they have adopted the new standard suggested, and consequently give actual work values to all their boilers. The writer is not certain as to who first took this step, but every praise is due to them as pioneers of a very desirable and important movement. Fully three-fourths of the makers are issuing their lists with actual values now, though some put the new figures side by side with the old approximate values, to show that the price, for size, of each boiler remains the same.

*Table of Work Values of Heating Surfaces in Boilers. New Standard.**

DIRECT HEATING SURFACE. — Whether the boiler is stoked in the ordinary way, or is arranged to take a charge of coal to last several hours.	One square foot to 30 superficial feet of radiating surface.

These figures are for an *average* square foot of heating surface, that is to say, not necessarily that part which comes nearest to the glowing mass of fuel, but to all the surface that receives direct heat.

INDIRECT HEATING SURFACE.—*For primary flue surface*, that is, for flues that receive the flame and heat immediately on leaving the fire-box, and which flues have, as a matter of course, a greater value than secondary or return flues next in order :—

If the flue is a flat, horizontal one, and the flame passes beneath it	One square foot to 12 superficial feet of radiating surface.
If the flue is a vertical one, and the flame, &c., acts upon the one side of it ...	One square foot to 10 superficial feet of radiating surface.

For secondary or return flue surface, that is, flues which receive the flame or heat as soon as it leaves the primary flues just alluded to :—

If the flue is a flat or horizontal one, and the heat passes beneath it	One square foot to 8 superficial feet of radiating surface.
If the flue is a vertical one, and the heat acts upon the one side of it	One square foot to 6 superficial feet of radiating surface.

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* This can only be held to apply to boilers provided with a correct area of furnace bars, as will be described directly.

No allowance has been made for horizontal flues which have the heat passing *over* them ; such flues are usually as near as possible valueless. The question of third and fourth flues has also been ignored ; these are of value when circumstances permit their use, and allowance can be made in proportion to the foregoing figures. For these third and fourth flues, and also the horizontal flues with heat passing *over* them, to do any efficient duty, the draught must be stronger than is usual in horticultural work of the ordinary character, as chimneys of even moderate height are not permissible in the gardens attached to a residence. In business establishments, or with professional growers, the unsightliness of a taller chimney is overlooked, and a more powerful draught is at once introduced. In this case the flues just mentioned, although still of the least value, add to the total efficiency, and all heating surfaces bear a greater value consequent upon the greater consumption of fuel, and heat evolved.

The standard just suggested is merely to take the place of the impracticable one hitherto used by boiler-makers, for boilers of the ordinary character and which constitute the greatest number in demand. It is, of course, unreasonable to retain the old impracticable figures, especially as they have led to many unfortunate errors being made. Builders and others who only occasionally use boilers are not all aware of the deduction to be made, and as the makers who mention it in their catalogues only mention it once, it is easily overlooked. Apart from the errors users have been, to an extent, led into by the approximate values, the American and Continental makers have been entertaining some surprise at our persistent retention of a misleading list. All American lists, whether the figures are for their particular climate, or reduced and corrected for English use, give actual values, and it has not been to our praise to have been so late in effecting an alteration. However, we are now in a fair way to have actual work values in every maker's list that is issued, and these values will, of course, do service perpetually. It is little short of wonderful that a great English industry as boiler-making is, has been carried on until so recently with such a trade list.

It may be held that the new standard suggested is too low, but such is not the case; it will only be found to give really effective results. It is quite of common occurrence for boiler users to adopt half Hood's figures, that is, purchase a 1000-feet (old list) boiler for 500 feet of 4-inch pipe, to ensure efficiency with economy, and to allow for possible irregularities in stoking or conditions; and presuming first cost is not all-important. If the standard just suggested errs in the least degree (for it is quite impossible to arrive at exact figures, conditions and other things never being twice alike) it errs towards efficiency. If it were otherwise it would lead to perpetual allowances being made for trifling circumstances. Apart from this, every boiler user will endorse the writer's opinion that a boiler should always be capable of over-doing its work if pressed a little. A boiler that answers quickly to any attention that is paid to the furnace gives the utmost pleasure to the user. It should also be thoroughly effective when the inclemency of the weather is inclined to tax its capabilities, otherwise (in glass-houses) the work of months may be instantly ruined or thrown back. Any boiler will heat a place in mild weather, or it might suffice in the bitter weather if it had constant attention, but no such risks should be run, especially as the remedy is gained with two or three extra inches in the length or width of the boiler.

The waterway in a boiler varies with its size—the smallest being 2-inch, the larger sizes being 3-inch and 4-inch. Occasionally boilers are made with still larger waterways, but these may be considered rather as exceptions to the rule, unless the boilers are of very large size. There is no gain in having an unusually large waterway, but the 4-inch size is worthy of recommendation for the large and also for moderate-sized boilers. In the first place, for a given area of direct heating surface (the part which surrounds the fire, and which is commonly called the inside) we get a greater indirect or flue surface with a 4-inch than we do with a 3-inch waterway, and by this means the efficiency of the boiler is increased, although but very little. Some makers value the heating properties of a 4-inch waterway boiler at one-eighth more * than a 3-inch, but this is most unreasonable, as the difference in actual results is hardly worth taking into consideration in practice, unless the boiler should be a very large one. But of course boiler-makers are quite justified in showing some greater heating efficiency in their lists, as an increased indirect surface does exist.

The chief advantage of a 4-inch waterway is its less liability to become choked with deposit (sedimentary dirt, foreign matter, or incrusted lime deposit) than with a narrower size. This is worthy of consideration, as there is every necessity to prepare for this trouble. In the best constructed apparatus in which care is used to exclude dirt, a sediment always accumulates in time, and in a horticultural apparatus that may be tended by a boy who charges it with pond or ditch water, a large amount of mud-like deposit quickly accumulates.

In every boiler there should be provision made for cleaning out any deposit that may accumulate, whether it be dirt or incrustation due to hard water. It is customary for this purpose to put what are called mudholes at a low point in each side of the boiler. These are merely fair-sized holes, drilled and secured by a screw plug, and provision is made in the brick setting for easy access and the removal of the plugs when necessary. Very commonly, and in fact usually, a pipe

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* An aggregate eighth, that is, giving to the little extra flue surface the credit of adding one-eighth to the total value of the boiler, whereas it does not add one-eighth to the flue or indirect heating surface alone.

A letter upon this subject addressed to the writer by a hot-water engineer of some note in London reads as follows: "The larger waterway does certainly increase the power of the boiler, because of the larger area of outside surface, but in my opinion not sufficiently to be worth taking into calculation. . . . I have hitherto found it rather unsafe to take the figures that appear in boiler-makers' lists. . . . I have always deducted one-third from the approximate work values that appear in most catalogues."

is brought from these holes straight through the brickwork in front of the boiler, these pipes being plugged at the ends; this makes the periodical flushing (to remove loose deposit or dirt) a simple matter, as a cane can easily be pushed in to disturb the dirt.

The accumulation of incrusted lime deposit is a more serious matter. This only occurs when what is known as "hard" water is used, this water containing lime (in solution), which is precipitated and adheres to surfaces most tenaciously when the water is heated.* It is more difficult of removal than the deposit of dirt—it cannot be flushed out. This question is more fully treated under "Hot-water supply for domestic purposes," and the causes, remedies, &c., are fully dealt with there. It should be mentioned here, however, that although the incrusted deposit is the most difficult to contend with, it fortunately shows itself very little in heating work, as firstly, it is the common practice to use soft water (rain water from ditches or ponds, or collecting tubs), which has no appreciable amount of lime in it. Secondly, if hard water is used it is not often changed, not more than a gallon or so being evaporated in a week or more (according to the size of apparatus), and as a given quantity of water has only a certain (very small) amount of lime in solution, the deposit is very trifling and does not become noticeable for a very considerable time. It is only in an apparatus that has the water continually drawn from it (as in a domestic hot-water supply apparatus, or in a kettle) that we get the thick incrusted accumulations.

If a heating apparatus is fed by a cistern with a ball valve, this usually means that the water is supplied from a water company's mains. Should this water be hard, as is nearly always the case in the southern half of England, an incrusted deposit of lime may appear. This will be governed by (1) the percentage of lime in the water, (2) the quantity of water evaporated, and (3) whether any water is drawn from the apparatus for watering purposes. This latter practice greatly aggravates the trouble.

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* The heating process throws down the lime, and softens the water. It is the same deposit or "fur" that we get in the tea-kettle when hard water is used.

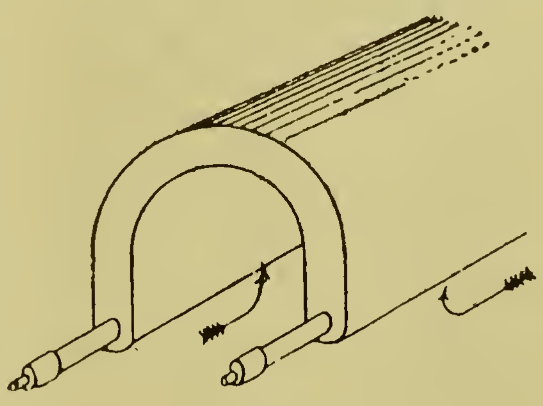

Fig. 114.

It has just been mentioned that what are technically termed "mudholes" should be provided with every boiler, these holes being situated one on each side, in front of the boiler near the bottom, and generally having a pipe screwed into each of them, as Fig. 114. The pipes come through the brickwork, which has to be erected in front of the boiler unless it is one of an independent character. The object in having these holes situated in the position shown is that any accumulated deposit, whether hard or soft, can be removed from the surface of the boiler where it is most likely to cause injury, which parts are pointed to by arrows in the illustration, nearly every fracture occurring here. These points can be reached with a rod or cane inserted from the front, through the holes referred to. If these bottom angles are kept clear the boiler should do many years' good service. If the boiler is one having a return pipe brought in upon one side only, it is the other side—the part of the boiler furthest from the return pipe—where the greatest soft deposit* will be found.

Again, referring to the question of large or small waterways to boilers, it may be considered that for medium and large boilers 4-inch is a desirable size, and no gain will be effected by using larger. An increased bulk of water is a disadvantage unless it is desired to secure a store of water, in which case it would be better to use a tank as a reservoir.†

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* The term soft deposit is used as embracing all matters of a dirt-like nature. The hard deposit of lime (carbonate or sulphate) is of a stony character.

† A tank is sometimes of service when a pipe has to be carried below the level of the boiler, as will be found described on a later page.

About the only case in which a store of hot water is useful is when an equable temperature is particularly needed with uncertain stoking. In this case a tank of good size might be put in connection with the apparatus, and provided it was well covered with some poor conductor of heat, it would provide a storage of hot water that would be circulated through the pipes and give up heat for some little time after the fire was out. This is a most unusual requirement, but nevertheless it may occasionally be resorted to, and is found useful in works of a peculiar or special nature.

It will be found in the description of boilers that follows this, that some are made of a very shallow shape, expressly for use with what is called "shallow drainage," that is, situations where water is met with (when excavating for the boiler pit) very near to the surface of the ground, so that a deep boiler pit is out of the question. Even those pits which are concreted round, or lined with iron, cannot be kept free from water if they are deeper than the point that the surface water rises to, neither can they be readily drained, as every pit should be, if possible.

Boilers are made of cast iron, wrought iron, and copper. The latter material is but seldom used by reason of its costliness. Cast iron is adopted by a few makers in England ; but in America it is a material that is used to the exclusion of all others with boilers for heating purposes, whether hot water or steam. It will, undoubtedly, make headway in England presently, but, at this moment, the wrought-iron boiler industry is a large one here, and our engineers, the majority of them, are scarcely inclined to use cast boilers freely yet. American engineers claim great superiority and many advantages for cast iron, and, as their experience and practice in heating works is some fifty times greater than ours, their ideas are worthy of consideration. Cast iron, as a name, is, in many people's minds, associated with a brittle and unreliable material, but this should not be so. It would be used to a much greater extent if the right kind of admixture of metal was used to produce a tough casting* which would not only withstand rather violent handling, but would last a long time without fracture from ordinary wear and tear.

Wrought iron is the material mostly used in England for boilers of moderate and large size, both of the independent and other kinds. The plates are generally jointed by a weld, this being cheaper than riveting, and is satisfactory in use; but with large sizes, riveted joints are resorted to. All boiler-makers' lists show two thicknesses of plate, viz. $\frac{5}{16}$-inch and $\frac{3}{8}$-inch, the price differing about 20 per cent. The latter thickness is always recommended, and if cost is not of primary importance it should be used. But it has often occurred to the writer that if a boiler of each quality could work side by side under exactly similar conditions it is doubtful whether the $\frac{3}{8}$-inch would give 20 per cent. more service than the $\frac{5}{16}$-inch. We have to remember that many, in fact almost the majority of boilers do not fail from actual wear, but become fractured by some accidental cause (accumulation of deposit, &c.), this being obvious in a great measure by the fact that the fracture nearly always takes place as shown in Fig. 12 (page 38). But it is not intended to recommend the thinner plate, as in good work it would be best to use the thicker quality, although the advantage gained may not be quite proportionate.*

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* To illustrate the difference in the natures of various brands of cast iron, the writer once saw a cupola man in a foundry breaking pigs of what is known as "white iron." A pig would break with one very moderate blow of a sledge hammer, and not only break, but fly in four or five pieces. Whereas a pig of superior iron, noted for its toughness and softness, was subjected to about fifteen to twenty of the heaviest blows with the same hammer, and, after all, had to be dropped across a block of iron set edgeways before it came into two pieces. Then, instead of a clean break, as is obtained with white iron, the iron bore the appearance of being torn asunder—a never-failing sign of excellence of quality. This foundry was devoted to the manufacture of cooking ranges, and the castings, if struck at the edge, would burr over, instead of having a piece fly off, as is expected as a matter of course with anything made of cast iron. A casting of good quality should not break even if dropped a moderate distance on to a stone surface, yet the average of castings met with have to be handled like glass.

There is another good reason for using $\frac{3}{8}$-inch plates, viz. that when the apparatus is one that extends some distance in a vertical direction, it necessarily brings a considerable strain to bear upon the boiler which is at the lowest point. However, this happens but rarely in horticultural works, and the reader is therefore referred to a later page, where the subject is fully considered, as it needs be, in heating buildings and high places.

The last, but important subjects to be considered (before dealing with the boilers themselves) are, the area of furnace bars needed for certain boilers, and some general features that should be studied in connection with furnace construction. With some of the boilers that are described later, there will be shown methods of setting them, particularly with the ordinary saddle boiler which so greatly resembles many of the more recent patterns, and is a guide in a great measure to the treatment of these others, so far as setting is concerned; but with all of these there is a certain recognised rule to be followed in deciding the size of the furnace bars. This rule requires almost as much consideration in practice as the one which governs the selection of the boiler itself.

Hood very correctly points out that the area of furnace bars should bear a distinct and fixed relation to the area of radiating surface, without any material consideration as to the size of the boiler. This, however, must be allowed a little latitude occasionally, as although with a certain area of fire-bars we can consume only a certain quantity of coal in a given time, whether the boiler be small or large (draught and other conditions being equal), yet with a larger boiler we should be getting better results generally; but under all ordinary conditions a fixed rule can be adhered to with a certainty of good results.* Occasionally a greater area is desirable when a greater consumption of fuel is required, but the special nature of the circumstances will decide what proportionate extra area is needed.

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* It might be mentioned that there is greater difficulty experienced by the boiler-makers in welding thin plates. A good welded joint is effected with $\frac{3}{8}$-inch plate more easily than with $\frac{5}{16}$-inch or $\frac{1}{4}$-inch plate.

If it is desired to get a greater heat by a proportionately greater consumption of fuel, this is better effected by increasing the area of furnace bars than by using ordinary sized furnace bars and increasing the draught. Of course, a certain amount of fuel will yield only a certain amount of heat, but to economically utilise the heat evolved is, as just stated, better effected by having a larger area of fire-bars with a normal draught than a small set of bars with a stronger or forced draught. It has been a recognised rule always that if the fuel can be had in a moderately thin layer spread over a good surface, burning brightly (as it would do under such conditions), better results will be attained than if the fuel is confined to a smaller area in a mass, with a forced draught. Another, though minor, objection to a forced draught is that it necessitates more attention being given, and it also causes undue wear and tear.

Hood's rule, or table, which is recognised and found correct at the present day, is as follows.

Hood's Table for Calculating the Area of Furnace Bars needed for certain Lengths of Pipe.

Area of Bars.	4-in Pipe. feet.	3-in. Pipe. feet.	2-in Pipe. feet.
75 square inches will supply	150	200	300
100 " "	200	266	400
150 " "	300	400	600
200 " "	400	533	800
250 " "	500	666	1000
300 " "	600	800	1200
400 " "	800	1066	1600
500 " "	1000	1333	2000

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* If in ordering a boiler the maker is asked to supply the fittings, he will send a grating or furnace bars of a suitable area, together with the furnace doors, dumb plate, &c., all of a correct size for the work the boiler is supposed to do. This is a convenience if the purchaser desires to avoid the trouble of calculating, &c.

It will be seen that, although the table is extended to eight lines, it really says that for all general purposes in which small to fairly large sized boilers are used, it can be laid down that each 100 feet of radiating surface should be allowed 50 square inches of furnace bars.

Hood's table, however, can only be applied to plain saddle boilers, as immediately we introduce a boiler with flue ways or cross tubes, &c., in it, we increase its power with regard to the radiating surface it can deal with, but we may not increase the size of the furnace or the lower part of the boiler in the least. And although in an instance like this the radiating surface capable of being dealt with is greater than with a plain saddle boiler, there is no need to increase the area of furnace bars proportionately, or in fact, at all.

When Hood fixed his standard of 50 square inches of fire-bars for 100 superficial feet of radiating surface, boilers with check ends, chambered flues, cross tubes, &c., were little known, or rather were accorded but little favour, but now they have a considerable demand, particularly where space is limited. Where we can get increased surface, particularly direct heating surface, and increased results for a given amount of fuel, without increased size, it is, generally speaking, a desirable end attained.

In practice it is found that, adopting Hood's calculation (which is strictly practical) for saddle boilers, a list, such as the following, gives accurate results under ordinary conditions, and with an ordinary draught.

The areas mentioned in the following table include the bars and the spaces between the bars. The table may be varied to suit special requirements, and no noticeable trouble is experienced if under ordinary circumstances the area is increased a little beyond the proportions given, but it is by no means ever desirable to decrease the areas suggested. An increased area with a low draught is better than the reverse. For every 100 superficial feet of radiating surface allow :—

Table showing the Area of Furnace Bars for Various Kinds of Boilers at present in Use.

	Square inches.
With a plain boiler	50
„ saddle boiler having one check or waterway end	45
„ „ „ two waterway ends (front and back)	40
„ „ „ one tubular flue	40
„ „ „ two tubular flues	38
With saddle boilers having check ends and tubular flues	35
If a boiler is fitted with a cross tube, the area of furnace bars can be reduced below the above figures for every 100 feet of radiating surface	5 to 10
Sectional cast-iron boilers, either English or American types, are worked with an average of about 20 square inches of furnace bars per 100 feet of radiating surface. This low allowance is sufficient, the direct heating surface being so extensive within a small area.	

From this table it will be seen that a plain saddle boiler, estimated to heat say 800 superficial feet of radiating surface, should have furnace bars of an area of 400 inches ; but this boiler, fitted with an oval cross (waterway) tube, would be capable of dealing with 1000 feet of radiating surface, though the area of fire-bars need not exceed the measurements above given.

In dealing with the following representative variety of boilers, no particular distinction will be made between those used for horticultural works and those that may be better adapted for heating buildings.

CHAPTER XII.

INDEPENDENT BOILERS.

Their chief use and advantages—Loss of heat from exterior surfaces—GAS BOILERS.—Fletcher's and Keith's—Care to be observed in fixing gas boilers—BOILERS FOR COAL AND COKE FUEL.—"Star" boilers—A coil boiler—The "Loughborough" boiler—The "Very" boiler—Vertical dome-top pattern, with and without waterway bottom—The "Ivanhoe"—The "Severn"—The "Columbia" double-cylinder boiler—The "Challenge"—The "Merton" sectional—The "College" American design—The "Python" sectional—Cast *v.* Wrought boilers.

THESE boilers, as the name signifies, are constructed in such a manner as to be quite independent of any constructional work in fixing. Assuming that they are stood upon a non-inflammable floor or base, there is no need of any brick or mason's work to make them complete. The connection with the chimney is effected by a pipe, and the furnace is made and enclosed in iron, and forms a lower part to the boiler itself.

It is seldom that independent boilers are used in horticultural works, except in small size. There is a very convenient form of boiler made for greenhouses of moderate size, as will be seen in the next chapter, but, except for this, brick-set boilers are the rule. For heating brick buildings, the brick-set boiler has been most largely used, and is so now i the work is of any magnitude. This has been due to there being few independent boilers capable of working a large apparatus. This will undergo a change presently, as the independent boiler is eminently suited for these works, and there will be found boilers in the following pages quite capable of dealing with the largest apparatus erected.

It is to be wondered at that, with a large system of pipes, a pair of smaller boilers is not more often used instead of a single one of full size. The expense would be but little more, if any; there would be no extra consumption of fuel, as the aggregate of size and power of the two smaller ones would only just be equal to whatever size a single larger one should be. And they would need no extra or special attention in use. The advantage of this arrangement lies in the convenient way the apparatus can be worked when the weather is not very severe. The size of a boiler is always calculated to meet the most severe weather—that is, to afford a temperature of say 65° F. when the thermometer is registering about 20° outside. This degree of cold may only occur on a very few days in winter, and at other times one smaller boiler will do the work, with a smaller consumption of fuel, leaving a boiler in reserve. In event of failure, or repairs being necessary, one boiler can be worked while the other is being attended to.

It is very desirable, and, properly speaking, necessary, to coat or surround independent boilers with some poor conductor of heat, otherwise the practical as well as the theoretical value of the boiler will vary according to the heat or coldness of its position and surroundings. There are very many materials that can be utilised for the conservation of heat of boilers, but not all are very easy of application. Slag wool or silicate cotton, for instance, is a material most highly suited for surrounding heated bodies, even those that attain a temperature that would ignite anything like hair felt, for it is non-inflammable, and is as near as possible a non-conductor of heat. As it is a wool-like substance, it would require to be encased round the boiler, and this is not convenient. Asbestos is another material of a similar character;* but there are now several patented compositions which are plastered on, and in which silicate cotton and asbestos possibly represent the chief ingredients; these are fairly easy of application.

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* Both these articles can be had in sheets and slabs, &c., but then they are not so easily applied to boilers as a cement compound.

The chief care with these cements is to see that the first coat is made to adhere to the metal, this usually being effected by well rubbing it on.

For an application of this material to be properly effective it should be put on sufficiently thick to almost wholly prevent loss of heat. It usually requires a layer or coating of 1½ inches to 2 inches thickness to do this (with the boilers now being spoken of), and if when the boiler is full of hot water the hand is applied to this coating and no heat is felt, it is sufficient indication that no waste of heat is occurring in this direction. If space and appearance are of no object, brickwork built closely round the boiler would answer admirably, but this is a clumsy method, and defeats the object sought in having the boiler of an independent character. Of course, if the boiler or any portion of it was situated in a greenhouse, or any place to be warmed, then there would be no occasion to cover it where the heat radiated was useful in effect and not wasted.

As before mentioned, it is intended to commence with the smallest practical form of boiler, and perhaps those heated by gas best answer to this description. Gas boilers are, however, made in sizes to do fairly effective work, but, as a rule, it is the smaller sizes that are in demand. There are still smaller appliances that may be correctly termed boilers, and which are heated by petroleum or paraffin oil. They usually have the radiating pipes in connection with them, and, as portable contrivances to warm a small plant-house attached to a residence, they fulfil a very useful purpose. A description of them is scarcely necessary here.

Fig. 115 represents an ingenious form of gas boiler, embodying in a practical form the suggestions made in a paper by Thomas Fletcher upon "Flame Contact."

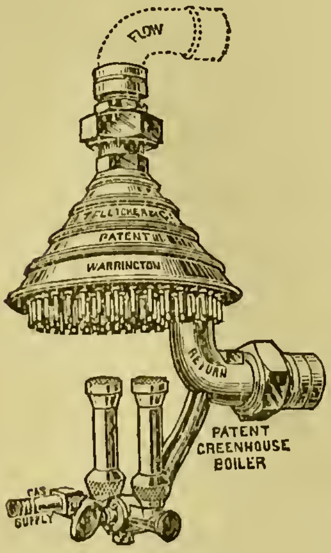

Fig. 115.

In this paper, which was read before the Gas Institute, it was stated that flame, whether from gas or coal (practically one and the same thing), had no actual contact with a vessel containing water at or below 212° (boiling point), and adduced in evidence were several experiments to prove this. The suggested remedy appears in the appliance just illustrated in the form of a number of *solid* studs or rods projecting from the heating surface, these projections acting as heat collectors and conductors. It was stated that flame readily had contact with bodies at a higher temperature than boiling water (with increased effect), commencing at about 400°, and this takes place with the projecting rods on the boiler. The heat is transferred from their extremities to the water by the high conductive power of the metal of which the rods are composed (copper). It might be inferred that the projections simply act as increased heating surface, and the same results would be obtained if the rods were hollow,* but this is not the case, as can be ascertained by experiment and subsequent calculation. Another peculiar feature with the solid rods is that they present fully twice as much heat-receiving surface to the fire as there is water surface, yet they are at no disadvantage, as a given surface of water is capable of absorbing heat at 2-5 times the rate that the same surface of metal (iron) is capable of receiving and transferring it.†

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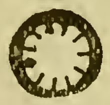
* If these projections were hollow, they would fail quickly with hard water, by becoming solid with incrusted deposit.

A limit is set to the length of these studs, as beyond a certain point they receive more heat than the water can as quickly absorb, and the extremities then perish.

† A boiler tube has been introduced which has practically the same effect as this, it being a tube of ordinary length and diameter, but having a series of longitudinal ribs or gills within it thus  which do not interfere with the flue brush, and are considered to give fully 30 per cent. better results than a plain tube.

Hood, as early as 1828, adopted the plan of having a great number of solid protuberances on the heating surfaces of boilers, first in the form of rods or pins, and subsequently in the form of continuous bars or ribs; and a Mr. Sylvester afterwards in 1835, and a Mr. Williams in 1841, both patented other adaptations of this idea. In effect Hood found the plan

The effectiveness of this principle is demonstrated with the boiler now referred to (Fig. 115). A small size, measuring 6 inches in diameter and 5 inches in height, is claimed to heat 40 feet of 2-inch iron pipe (practical quantity) without undue consumption of gas or specially favourable conditions. It requires no support to itself, as the rigidity of the pipes is sufficient for such a light contrivance, but a boiler of this kind requires to be fixed outside the greenhouse, as will be explained directly.

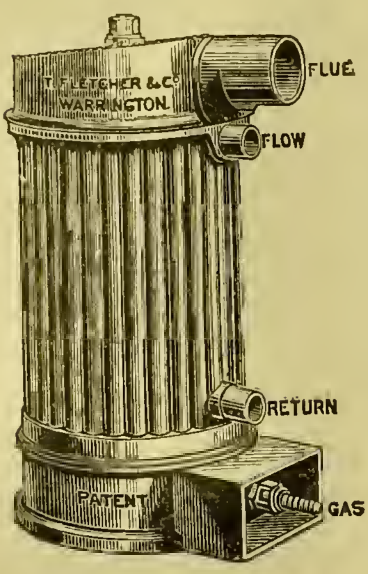


Fig. 116.

Fig. 116 illustrates another boiler having the same principle applied to it, but differing considerably from the last so far as shape is concerned. This boiler is made of cast iron, and one particular feature is that its construction is such that it can be used for supplying hot water for draw-off purposes, notwithstanding that a hard deposit may accumulate. To admit of this a lid is provided, easy of removal, that gives access to all parts where the accumulation may occur. Provision is also made for easy removal of soot should the light be attended to carelessly, causing soot to be formed and deposited.

Fig. 117 illustrates Keith's patent gas boiler with an ingenious principle of forming the construction in sections. This principle is adopted by the maker in nearly all his boilers. A particular gain is effected by this arrangement in various ways, the chief being that by making these boilers

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very successful, but, apparently, no part of the resulting gain was in any way credited to the fact that the flame readily came in contact with the extremities of these projections; whereas it would not do so with the plain boiler surface. No mention of this fact is made by Hood, so doubtless it escaped observation. Mr. Keith found a greater practical value in this improvement, and more recently adapted it again with success; but he found care was needed in the use of these projecting parts, as they are apt to collect soot, &c., and thus defeat their usefulness.

in parts of moderate bulk a great complexity of form can be more readily given them (for they are of cast iron), and thus the greatest possible heating surface obtained by tubes, convolutions, &c. This could not be so well effected if the boiler was constructed any other way. In boilers of large size (for coal burning) this arrangement simplifies the difficulties of transport and fixing. It also enables a very great variety of sizes or powers to be readily supplied (but this latter is chiefly to the maker's advantage). It will be necessary, however, to refer to this style of boiler again later in the chapter; fuller particulars can then be given, as most details apply to the sectional boilers constructed for coal and coke burning. The particular boiler now being referred to (Fig. 117) is 13 inches square, but varies from 15 to 28 inches in height, depending upon the number of sections used.

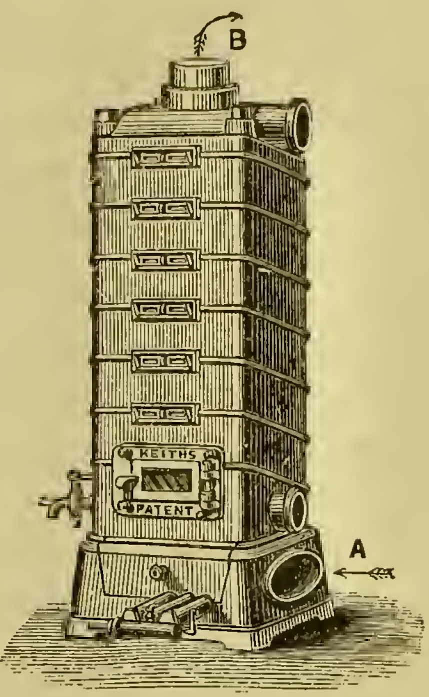

Fig. 117.

Gas boilers are not made to heat more than about 100 feet of 4-inch pipe (200 feet of 2-inch), but if in demand, they could be made larger to order. If, however, a larger quantity of pipe than the above had to be heated by gas, it would be better to have a group of the 100 feet boilers, a battery so to speak, connected together, than one of an unusual size.* They could then be used one or more at the time as desired. Every gas boiler, whether small or large, should, properly speaking, be fixed *outside* a greenhouse. Under some circumstances, and where they receive attention and care, they do well inside, but this should be considered merely an exception to the rule, and by no means be regarded as a precedent even by those who have fixed them inside successfully. Even when so fixed, the burnt gases, as they are called, the products of combustion, must be carried outside. Small stoves have sometimes been fixed inside, and discharge their products there without appreciable ill effect, provided a means is adopted of arresting the sulphur fumes (sulphurous acid SO_2) that are always given off from gas stoves. These fumes are particularly hurtful to plant life, even in the small volume such as we get from a single gas-burner for instance, if the area be limited. The question as to the different properties of the products of combustion from gas-burners will well bear a short explanation, as new gas stoves for various heating purposes are being introduced every season.

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* The chief reason why larger gas boilers are not made is that the demand would be so limited; for if any large quantity of pipe had to be heated, a gas boiler could not do it at all so economically as a boiler heated by coke.

The products derived by the combustion of carburetted hydrogen (coal gas) burnt from a Bunsen or atmospheric burner, which is almost exclusively used in heating work, consist of carbonic acid (CO_2), carbonic oxide (CO), and water (H_2O),* and some other gaseous matters, the results of impurities, which cannot wholly be eliminated in the manufacture. These impurities, with one exception, are either harmless or in such small quantity as to be of no consequence. The exception is sulphurous acid, which is brought about by the combustion of a small percentage of sulphur which is always carried over with the gas in the manufacture, and at present cannot wholly be disposed of, although every effort is made to effect its removal.

It is the sulphurous acid, carbonic acid and carbonic oxide gases that are the objectionable elements in the products, but the former is most hurtful to foliage in horticultural work. It has been mentioned that small stoves may discharge their products into a greenhouse without any noticeable effect, provided the former of these two substances is arrested. This is because carbonic acid in limited quantity is not injurious to plants, it being their food,* but even this latter substance must not be present in any volume, as apart from its effect upon plants, it would then become hurtful to human life, causing asphyxiation. With small gas stoves the removal of the sulphurous acid is generally done by taking advantage of the great affinity this substance has for water. One of the products of combustion is water, as just explained, and if this water of combustion is condensed by being brought into contact with a cooling surface before it escapes, it will be found to have collected the sulphur with it. The carbonic acid then goes free, inodorous and tasteless, and not observable as when it carried the unpleasant odour of sulphur with it. This has led a good many makers of gas stoves to perpetrate what looks greatly like an imposition upon the public, as there is an appliance of this kind now made called a "condensing" stove, which acts in the manner just explained, the water of combustion being condensed † by having to pass through two cast-iron tubular columns. A maker's list before the writer distinctly states that "all the products of combustion are condensed." We must charitably attribute this assertion to ignorance, as Nature lends her aid to the deception by making the carbonic product quite unnoticeable to the average person after the sulphur is removed. It is fortunate this style of stove cannot well be made in large size, for the volume of carbonic acid and oxide gases then given off would speedily be dangerous in a small or close apartment.

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* Of course another, and the chief, result of combustion is heat. See Combustion.

There are two chief objections to having a gas boiler in a greenhouse. One is the possibility of the gas escaping (by accident, carelessness, or other cause) unburnt,‡ this being firstly an element of danger by explosion, and furthermore it is just about as injurious to plants as the sulphurous acid just spoken of. The second objection is the liability of the products of combustion being discharged into the house notwithstanding the flue provided to carry them outside.

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* Plant life absorbs, and is nourished by carbonic acid (but in daylight only). The carbon is taken up, and goes to make living material, and the oxygen is set free.

† Approximately it will be found that the greater part of a pint of water can be brought down from every 30 feet of gas burnt, the quantity varying, however, with the area or coolness of the condensing surface. This water has a very unpleasant smell, and acid properties.

‡ For this reason, the flue pipe from a gas stove should not be carried into the brick chimney of a house, as an escape of gas from the stove might bring about serious results.

There is an idea much too prevalent, that a piece of pipe taken from the stove through a wall constitutes a sufficient flue for a gas stove, but nothing could be more incorrect: *a flue to a gas stove must be erected and carried out in every detail the same as a flue for a coal stove.* It is because the ill action of the flue cannot be very well noticed with a gas stove like it can when there is smoke. These flues are commonly put up upon some hypothesis of the workmen engaged (and their ideas are sometimes extraordinary),* the consequence being that on many days (depending upon the direction of the wind usually) the products will not pass out of the flueway at all, but insist upon coming into the house. The question of flues or chimneys will receive proper treatment in a later chapter (see Chimneys), and it will therefore suffice to mention here that the flue from a gas stove should rise above the house top, that is above the highest ridge, the same as any other chimney always has to terminate to be effective.

If the boiler is fixed outside the house it is still necessary to carry the flue up to a sufficient height, for although the escape of combustion products will not then materially matter, the down-draught will seriously interfere with the proper working of the burner (usually by blowing the light out), sufficiently so in all probability to render the apparatus useless. It must also be remembered that in an iron flue pipe a deal of condensation will most probably take place, depending upon the situation, and provision must be made for the disposal of the constant stream of water that will be trickling down it if the products of combustion become sufficiently cooled to bring about this result.

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* An exceedingly common idea entertained by many, even well-informed people, is that if a coal stove or grate is rendered useless by reason of the chimney having a defective draught, a gas stove can be successfully substituted. The supposition is that the gaseous products from the latter will pass up the chimney, being in no way interfered with by the bad draught, though exactly similar products from a coal fire, but carrying a little soot with them, fail to ascend. No idea could be more incorrect—in fact, it borders upon absurdity; and, although not entertained by specialists, it is very prevalent amongst workpeople.

When a gas boiler is fixed outside the house, it should be in a shed or similar place, otherwise it becomes necessary to surround it with a box-like structure, a little house, to protect it from the elements, particularly from strong winds, which will be found to interfere seriously with its steady working unless some method is adopted to guard against the trouble. This enclosure must not be anything like air-tight, as the burners, like a coke furnace, must have a copious supply of air to effect combustion ; and in addition to this, as the burner will most probably be of the atmospheric type, a free supply of air must have admission to this also, otherwise the peculiar character of the burner will be destroyed, and the worst results ensue. A grating, or strip of perforated metal, is all that is needed to ensure the necessary supply of air, but let this be of fair size, and insert it in the side of the structure that is least exposed to the wind.

A very necessary precaution in the use of a gas boiler, particularly with one that is enclosed, is never to turn on the gas until the light is ready to be applied, and before the light is applied it is a wise precaution to open wide the door of the enclosure, so that any possible collection of gas may be dispersed. If a burner is blown out by the wind there is instantly a source of danger, by the escape of unconsumed gas that takes place.

Consideration can now be given to the ordinary type of independent boilers which are used with coke fuel.* These outrival gas boilers in variety, also in power, and although they may need a little more attention in stoking and occasion a little trouble by dirt, they are considered more reliable, and there is less trouble in other ways. Very many of them are made to admit of economy in attention by taking a charge of fuel sufficient for many hours (depending, however, upon the way the flue damper is used).

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* Occasionally ordinary and small coal is burnt in independent boilers, but it is objectionable in many ways, and should never be used if coke can be obtained (this is not always possible, if the boiler is in some remote country place, and no gas-works within very many miles). The chief advantage with coke is its adaptability for charging purposes ; for as fast as the lower part of the charge burns away, some more falls to replace it, and this could not be relied upon with coal, which fuses and cakes into a mass. Good anthracite coal answers well.

Figs. 118 and 119* illustrate the least powerful and least expensive of these, yet having all the essential features and conveniences of the larger ones. These are usually known as "Star" boilers, but different makers give them different names to suit their own purposes. This pattern is not confined exclusively to one manufacturer, it can be seen in nearly every boiler-maker's list that may be taken up. Both have top feeders, that a good charge of fuel may be put in at once, but Fig. 119 is particularly adapted for this, the extended portion on top being provided expressly to take a greater quantity of fuel. The fuel gradually falls, and comes within the area of

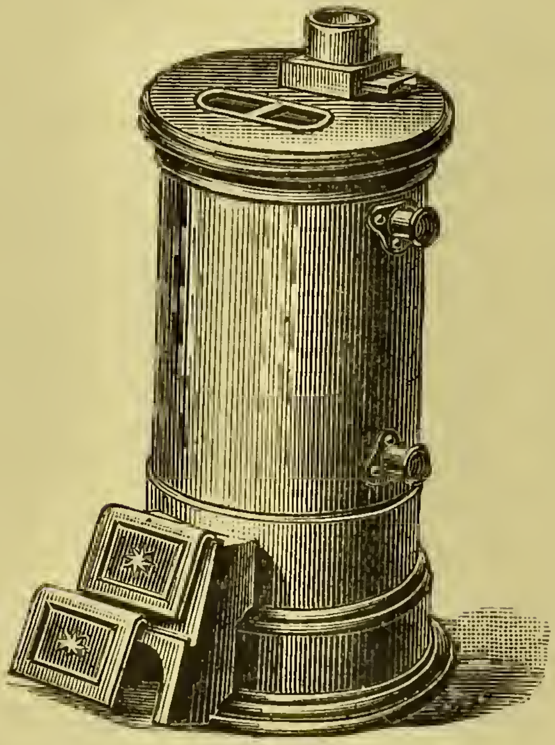

Fig. 118.

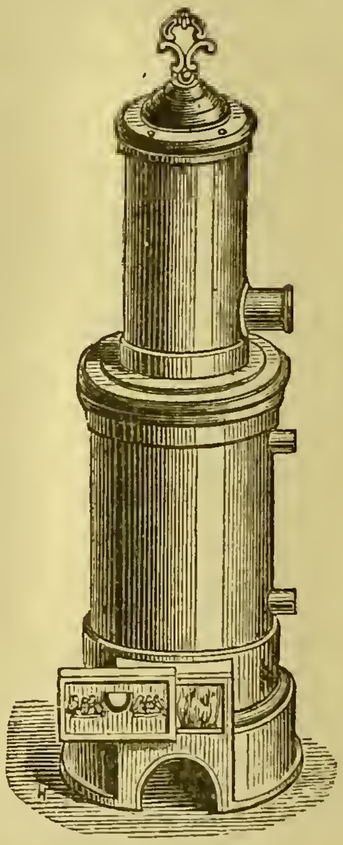

Fig. 119.

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* Made by Hartley & Sugden, Halifax (England).

combustion as that nearest the furnace bars is consumed. This advantage is greatly heightened by having the boilers, and also this extended fuel chamber, slightly conical in shape, as this prevents all liability of the fuel "bridging" itself, that is, refusing to fall. Added to this, the conical shape causes the sides to slightly overhang the fire, and the more this can be done, the better the results.

The writer would much like to see a boiler of this class or the "dome top" (presently to be mentioned) provided in every private residence of fair size to furnish hot water for domestic purposes, instead of the customary "high-pressure" boiler that is fixed in the kitchen range, The results with an independent boiler are so much more regular, not depending upon the cooking (which regulates the attention to the fire). The charge of fuel spoken of would keep the water hot night and day, and there would be plenty in the early morning, when there usually is none. In many cases there would be an actual saving in fuel, for it is really astonishing how much more quickly a cooking range acts when it has no boiler in actual contact with the fire, and how very economical in fuel it at once becomes (see "Hot Water Apparatus for Domestic Supply").

The boilers just referred to (Figs. 118 and 119) are made to heat from 120 to 500 feet of 2-inch pipe (actual quantity). Both are made in exactly the same sizes, so the disparity in the illustrations is rather misleading. The pipe sockets and flue nozzle can be had on right, left, or at back, as desired.

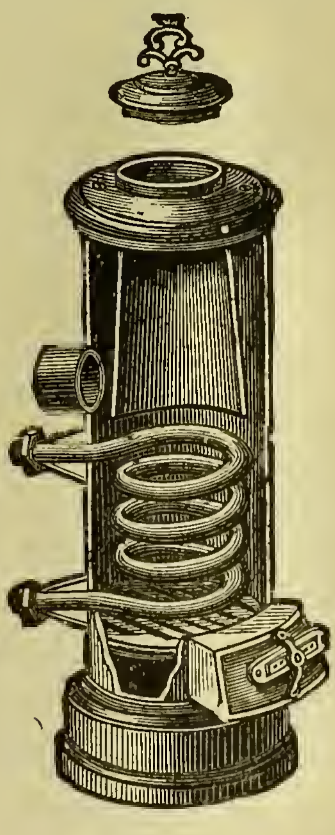

Fig. 120.

Fig. 120* represents what is generally known as a coil boiler, consisting of an outer iron case with the usual furnace fittings, but instead of having what is recognised as a boiler it has a coil of pipe placed so that the fire acts strongly upon it. This is shown in the illustration, which exposes the interior of the boiler. This boiler is also of small size, to heat from 100 to 450 feet of 2-inch pipe, but it has all the necessary fittings complete, and it will take sufficient fuel to last the night without attention.

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* Also from Hartley & Sugden's catalogue.

A coil, under some circumstances, may be considered the most powerful form of boiler (for the space it occupies) ever introduced, as it is wholly direct heating surface, and is also wholly in contact with the glowing mass of fuel. There are, however, objections to its use, but which are greatly obviated by using a large-sized pipe, as will be referred to when treating brick-set boilers.

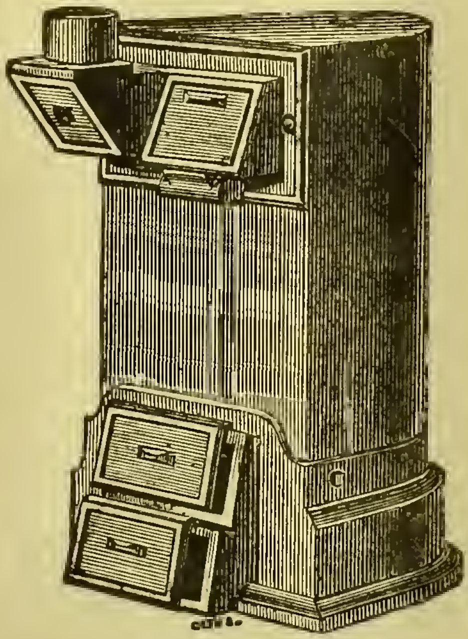

Fig. 121.

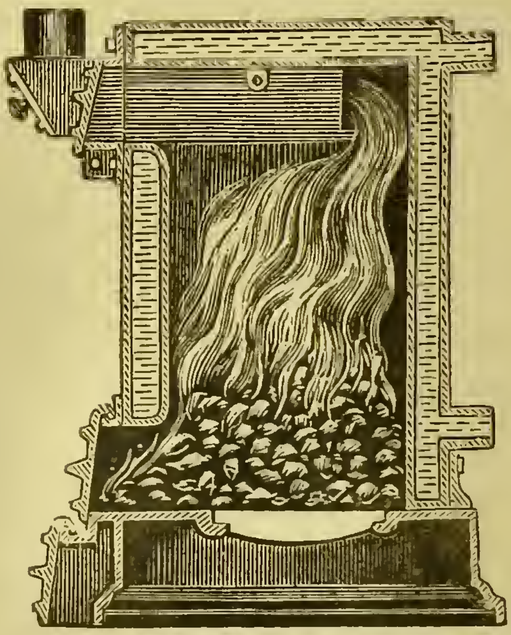

Fig. 122.

Perhaps the chief objection is in the smallness of the pipe, which permits of a stoppage and subsequent fracture by the accumulated dirt. Any such accumulation is difficult of removal, and precludes the use of a coil in anything like a complex form.* There is no objection to a coil of this description upon a small scale, as the evaporation and consequent replenishing of the water supply is not great, and there should be a proportionate decrease of the dirt that finds its way into the pipes. It is a common and very convenient arrangement to put a coil of two or three pipes into an ordinary grate for the purpose of heating a radiator in another room of a residence, as will be found illustrated with the examples of apparatus for brick buildings.

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* In heating works upon the high-pressure system, large coils of small pipe are invariably used, but in this case the apparatus is sealed, and all dirt matter is thus excluded.

Figs. 121 and 122 show a description of boiler commanding a large sale, and which has received much favour since its first appearance a few years ago. It was first introduced under the name of the "Loughborough" boiler, as it originated in that place, and it fulfils a decided want. Its peculiarity consists in its being adapted for building in the thickness of a wall (see p. 62), so that all the stoking and feeding doors are practically away from the greenhouse, yet the pipe connections are inside, and every inch of pipe does useful work. This saves the cost of providing connecting pipes between the boiler and the radiating pipes (so commonly necessary with independent boilers which cannot always be fixed near to the house) and also the loss of heat that takes place from these connecting pipes unless they are well protected.

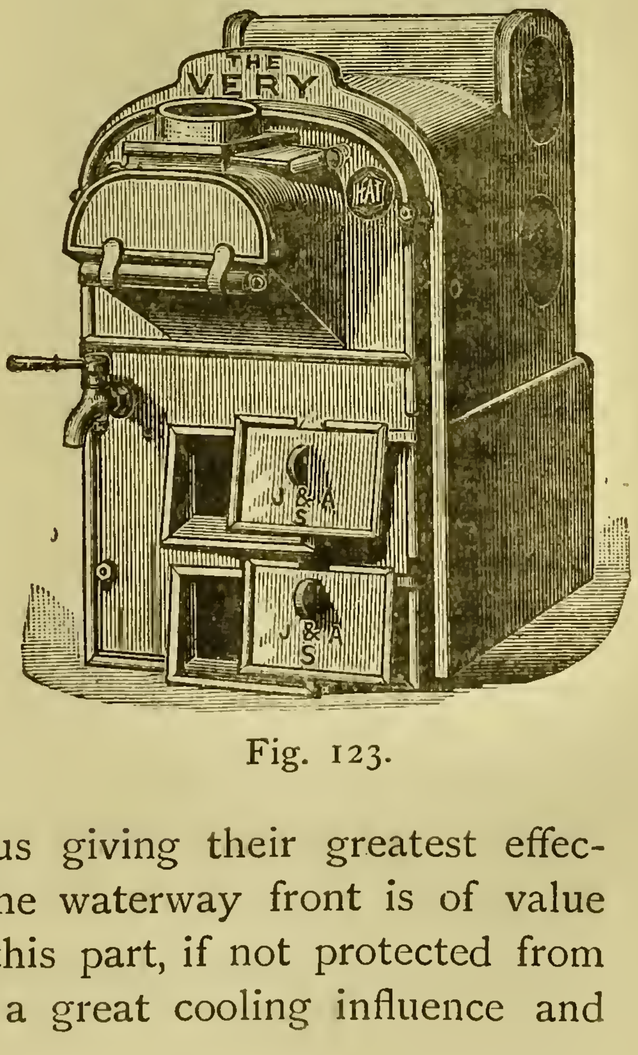

Fig. 123.

It will be noticed that there is an arrangement inside which prevents the flame and heated gases taking a short cut up the front of the boiler and out of the flue way, and they are instead compelled to come in contact with the back and sides and impinge against the top, thus giving their greatest effectiveness. It is doubtful if the waterway front is of value proportionate to its cost, as this part, if not protected from the weather, must experience a great cooling influence and prejudice efficacy. These boilers are made to heat from 300 to 1200 feet of 2-inch pipe, and the smoke nozzle, which is fitted with a damper, can be placed on right or left side of the front, as desired.

Fig. 123* is the "Very" boiler, which can either be used in an independent character, or fixed in the thickness of the greenhouse wall. The positions of the pipe holes are very ingenious, and in the majority of cases must prove of greater convenience than top or back connections. This boiler has no waterway to the front, and there is really little value in having it if it is to be exposed to the weather. If fixed in the thickness of a wall, the front would very probably be exposed in this way.

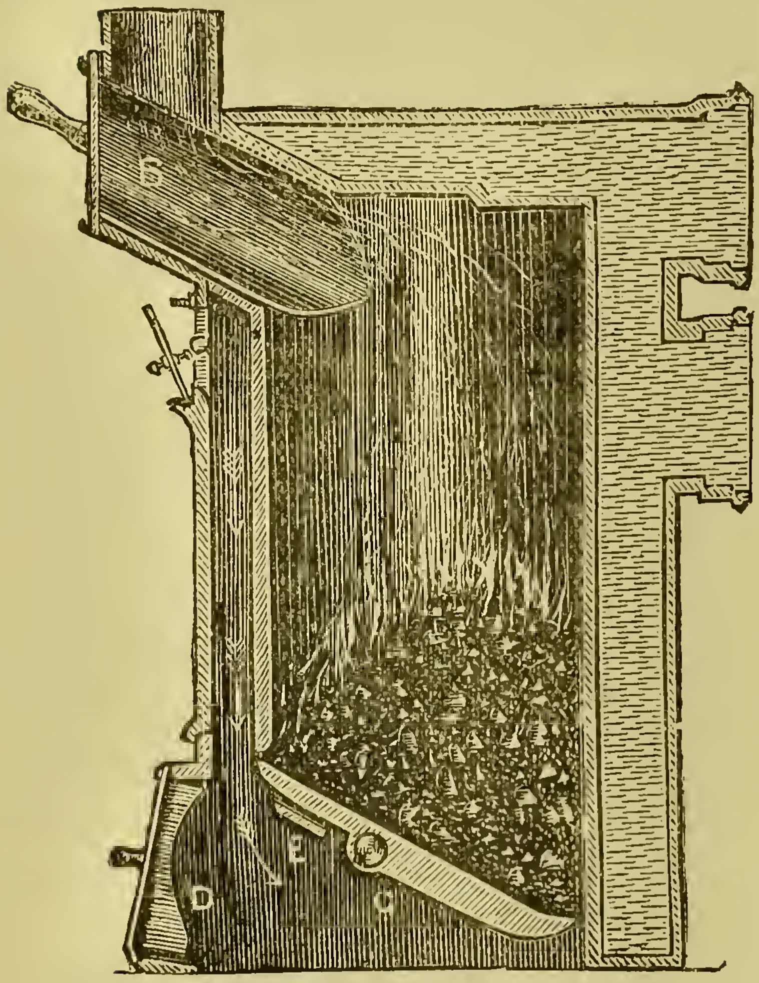

Fig. 124.

Fig. 124† is a boiler somewhat similar in character to the one just described, being suited for independent use or for fixing in the thickness of a wall, but it has one or two improvements that are novel additions to a stove of this description. This is called by the makers "The Horse-shoe boiler," as the plan of the boiler portion is of this shape, extending round the back and the sides in a semicircular form There is no waterway across the front, and, as just mentioned, none is needed; but instead of this there is a peculiar arrangement for the inflowing air to pass down just inside the front as illustrated, so that it becomes highly heated before it enters the fire. Another feature is what the makers call a revolving bottom grating. This, however, does not revolve, but can be made to oscillate or rock, so as to shake out the ash that accumulates and chokes the draught. A further detail peculiar to this boiler is an automatic or self-regulating air inlet, shown as a flap in the illustration, just below the feeding door. This flap acts upon the principle of Dr. Arnott's ventilator, in the fact that it can be set so as to adjust itself to the draught, a feeble draught leaving it full open, a strong draught drawing it partially close. This improvement is worthy of commendation, as it is in reality a self-acting damper, a thing very much desired, but, to the best of the writer's belief, not yet made in a perfect form, a form that will prove itself efficient at all times under all conditions. If the one now in question acts perfectly, the maker (or inventor) is deserving of the highest praise.

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* Made by Jones & Attwood, Stourbridge.

† Kinnell & Co., Southwark, London.

It will be readily understood that a damper does not of necessity have to be in the flue, as a provision for regulating the inflow of air to a fire checks or accelerates combustion just as well as a provision for regulating the draught up the chimney. In both cases the passage of air through the fire is controlled equally, and this controls the speed of combustion. A self-acting damper evinces its utility particularly when the draught in a chimney is variable (as is frequently the case, for the wind and weather will commonly bring about this effect), as it will then accommodate itself to the varied conditions, and the draught or passage of air through the fire will remain regular.

Another good feature in this boiler is that the waterway is continued below the fire-bars. This is a plan that can be had with almost any wrought-iron independent boiler, if so ordered ; it could also, with some extra trouble, be arranged with brick-set boilers. It incurs a little extra expense, but is even better if the waterway is also brought right beneath the ashpit, as in Fig. 125.* The advantage gained is that accumulations of sedimentary matter (dirt) which always settle at the lowest point, are precipitated and collect below the fire, so that however much it may accumulate at this point, its effect is not injurious. It is only when the deposit is successful in keeping the water away from the boiler plate *against which the fire acts*, that harm ensues or a fracture occurs. Were there a return pipe entering the boiler at the bottom just above the level of the fire-bars, this pipe would more readily get stopped with dirt if the boiler terminated at the fire-bars, than it would if the boiler were continued below.

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* From Hartley & Sugden's catalogue.

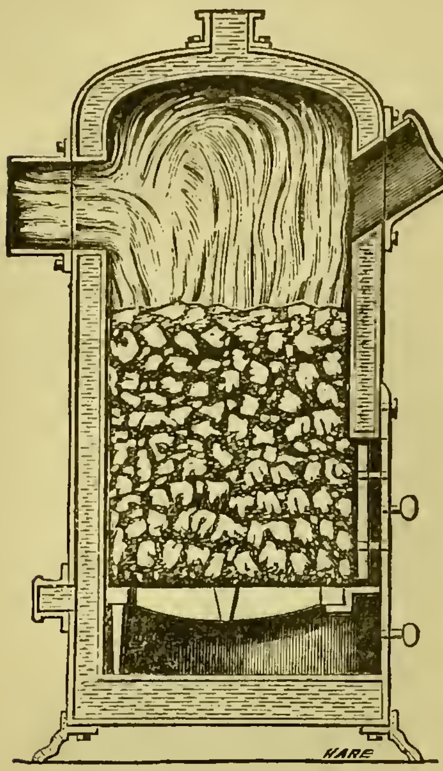

Fig. 125.

The desirability of having the waterway right across the bottom beneath the ashpit, as Fig. 125, consists in that it permits the whole accumulated matter to be removed from one mudhole (if a good-sized one is put) as the raking instrument when inserted will reach all around the lower part, as can readily be understood.* This advantage applies chiefly to boilers that are circular in form, as most independent boilers are. It can be seen how difficult it is to clear out the deposit from the cylindrical portion of the waterway, unless some five or six manholes are provided, and then it cannot be done so well. The waterway bottom really forms a catch-pit or settling bed for sedimentary matter.

With hard deposit ("fur") the waterway bottom is of great advantage though in a different way. When this matter is precipitated it adheres to the part it is deposited upon, if the surface is at a high temperature. Now the surfaces bounding the fire (if a waterway bottom exists) are vertical, and consequently a very small proportion of the deposit adheres here; the major portion falls very naturally straight down, which carries it below the highly heated area. On the other hand, if the boiler terminated on a level with the fire-bars, as is most usually the case, practically the whole of the deposited matter must collect just at the point where the greatest heat is felt. Consequently, it becomes exceedingly hard, and the quantity becomes sufficient to keep the water away from the iron, and a fracture ensues. In addition to the obvious disadvantage of terminating the boiler at the furnace bars, which practically assists the deposit in injuring the boiler, there is another drawback in the fact that at the angle immediately nearest the fire bars there has necessarily to be a weld or joint, a weak point where it should be strongest. This is, of course, all remedied by carrying the waterway down below.

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* It can be plainly seen that it is at the boiler and not in the pipes where the greatest amount of dirt accumulates, as the boiler is at the lowest point, all pipes sloping down towards it.

What should be aimed at is to prevent a collection of deposited matter of any description being formed in close proximity to the fire, the place where it can have the worst effect. The deposit is practically harmless above or below where the glowing fuel is situated. A further advantage in continuing the waterway to the bottom and making the boiler independent of a base is, that occasionally a leakage of gaseous products may take place between a boiler and its base, and if any part of the boiler is in the house these gases would prove objectionable. But this could only occur when a down draught manifested itself in the chimney.

In dwelling so strongly on the effects a collection of dirt or other matter may bring about, the use of this form of boiler and others in horticultural works is chiefly in mind. It happens, however, that this vertical dome-top boiler is used as much, or perhaps more, in residence heating, being rather a favourite pattern for this work. In this case the question of dirt and deposit does not require so much attention, as the boiler would undoubtedly be fed with clean water from the house cistern. There would also be no likelihood of water being withdrawn, to bring about the lime deposit from hard water, consequently for residence work the waterway bottom is more often omitted than not. The boiler, Fig. 127, is then commonly used.

Fig. 126* shows in section the "Ivanhoe" boiler, another of the class that is suited for building in the thickness of a wall, as illustrated. In most respects this is similar to other boilers of this character, the chief variation being that with the small sizes only the inner side, the back, has a waterway, the front and right and left sides being iron and fire-brick; but to increase its effectiveness the waterway can be continued round one or both sides. This boiler has the advantage of being a very good-looking shape, which adapts it either for fixing in a wall or standing clear.

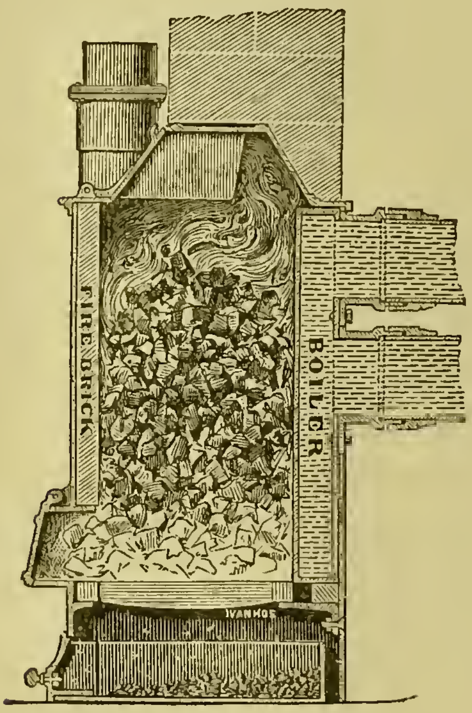

Fig. 126.

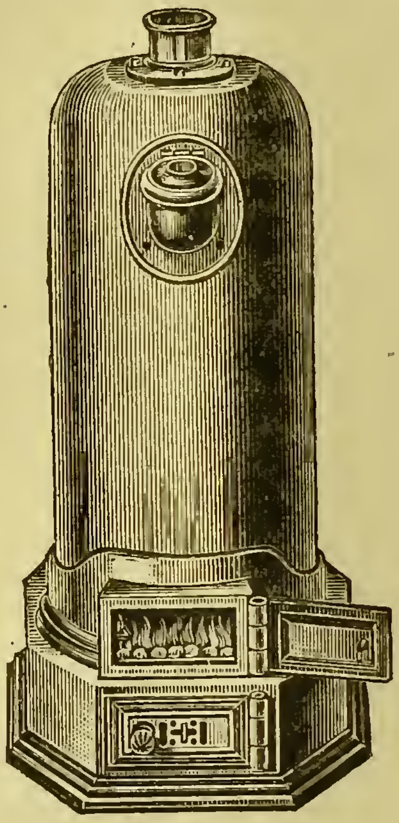

Fig. 127.

Fig. 127 is the ordinary character of welded dome-top boiler, the dome having the flow pipe on its apex, which favours good results more than when the flow pipe has to start horizontally from the side. As mentioned, this is a boiler that has considerable use for residence work, not that its general effectiveness is higher than other boilers, but owing to its simple form and easy regulation. It is, practically, a plain cylindrical waterway shell, with the waterway carried over the top. This form is convenient for receiving a charge of coke, so that the boiler does not require replenishing with fuel more frequently than three times in twenty-four hours. This is of considerable advantage in private residences, or any place where a maid-servant or a page-boy attends to the fire. It is made to heat from 350 to 3250 feet of 2-inch pipe theoretical quantity, or 250 to 2100 feet actual quantity. For cleaning, there should be two or three 1½-inch mudholes that a cane can be worked through to disturb the sediment. This boiler is not suited for heating hard water if the heated water is regularly withdrawn for any purpose. This would result in an incrusted lime deposit occurring, which no cane could possibly loosen, and the boiler would soon fracture (see p. 218).

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* Manufactured by Robert Jenkins & Co., of Rotherham.

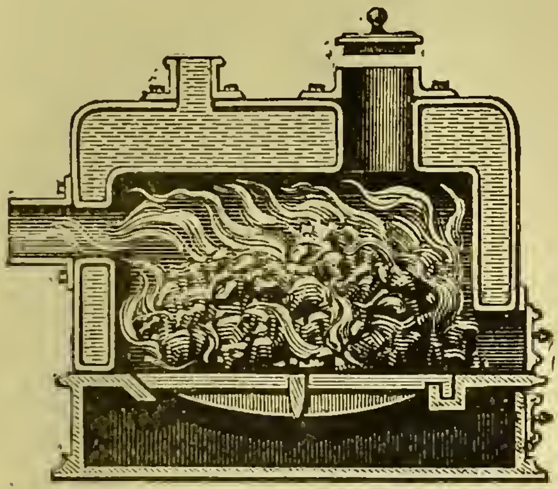

Fig. 128.

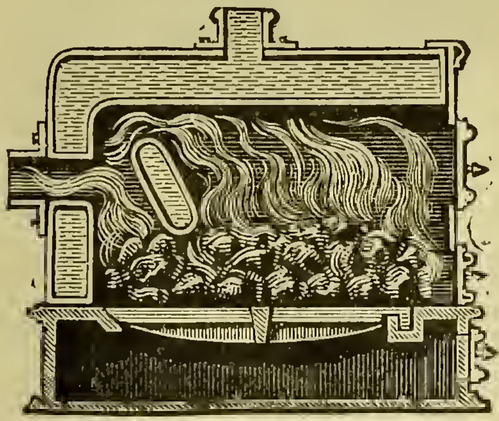

Fig. 129.

Fig. 128 is a description of boiler that can be recommended for general purposes, being effective (heating from 800 to 2200 feet of 2-inch pipe), and very compact in shape. This is in reality a saddle boiler with terminal or waterway ends back and front, a boiler that will be strongly recommended when treating of brick-set boilers. The waterway front end, however, necessitates a top feeder as shown, not that this is a disadvantage by any means, quite the reverse, as it enables the boiler to more readily be charged with fuel to last several hours without attention. Horizontal boilers can be charged with fuel in this way as easily as the vertical shape.

Square boilers are more easily cleaned than the cylindrical shape, but both shapes are better for having the waterway carried down beneath the firebox if much sediment is likely to occur. It is not necessary otherwise. This shape of boiler is in some respects preferable to the vertical, being more effective and having less heating surface covered by the store of fuel. With a vertical boiler quite half the interior surface does but little work when charged full of coke, but with this horizontal pattern there is a greater proportionate surface exposed to the glowing fuel. In cross section this boiler is of a square shape, vertical sides with a flat top. There is something to be said in favour of this, and it will be found spoken of when describing the ordinary saddle boiler.

Fig. 129 is a boiler very similar to the last, but without the waterway front. This can, of course, be had or omitted just as the user wishes, but, as shown, no top feeder is actually needed if the waterway front is not used. This illustration is introduced chiefly to show the waterway tube that passes from side to side across the fuel chamber. This is an addition that never fails to materially increase the heating power of a boiler, as it is wholly direct heating surface. The tube is situated at a point where it cannot fail to receive the full benefit of the heat, at some times being almost enveloped with fuel in a glowing state. Cross tubes in boilers should

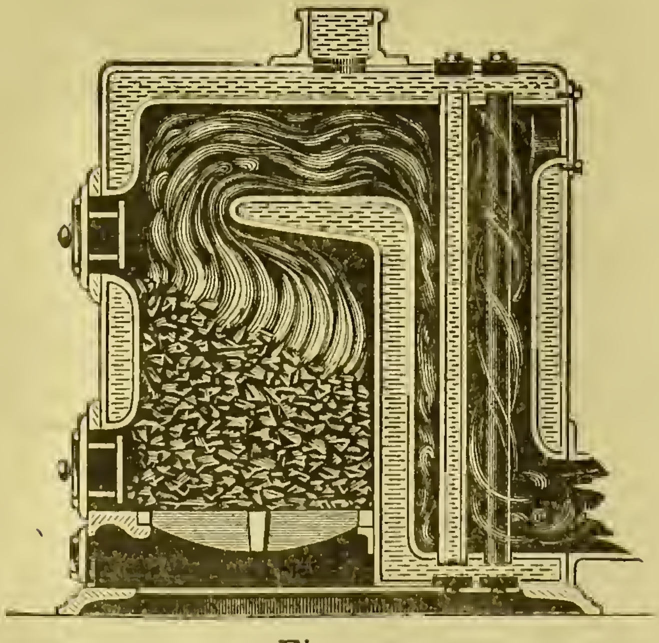

Fig. 130.

not be horizontal. They should slope from side to side, or be quite vertical.

Fig. 130* is the improved "Severn" boiler, a very effective form of vertical independent boiler, it having, in addition to the customary waterway sides and top, an intervening waterway bridge that the flames and heated gases impinge upon. In addition there are a series of vertical tubes in a flue chamber behind, as shown. A bridge or any device of this kind which intercepts the free exit of flame has a pronounced effect in increasing a boiler's efficacy. Flame, as has been explained elsewhere, has a decided tendency to avoid contact with surfaces if it can, and flame without contact does very little useful work. The tubes behind, lying as they do directly in the path of the escaping heated products, add very greatly to the effectiveness of the boiler, utilising what would otherwise be waste heat.

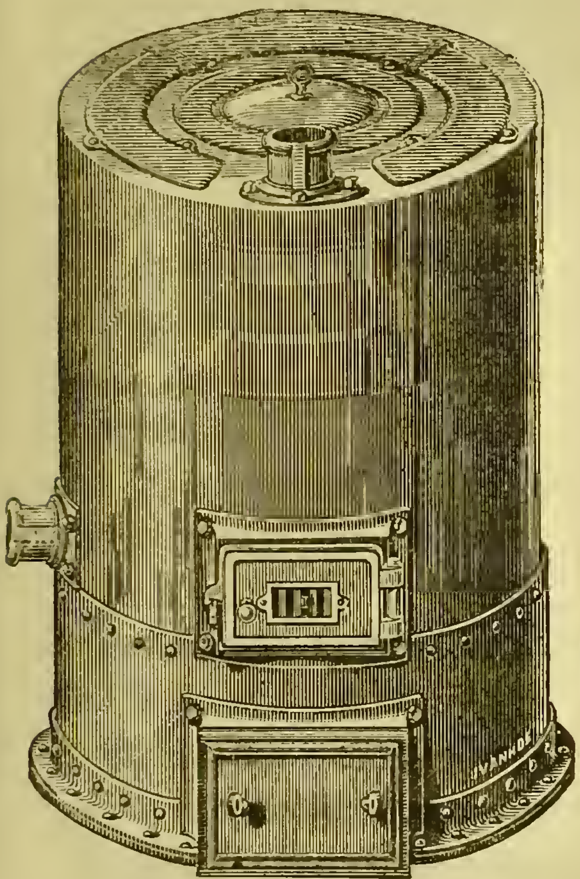

Fig. 131.—Elevation.

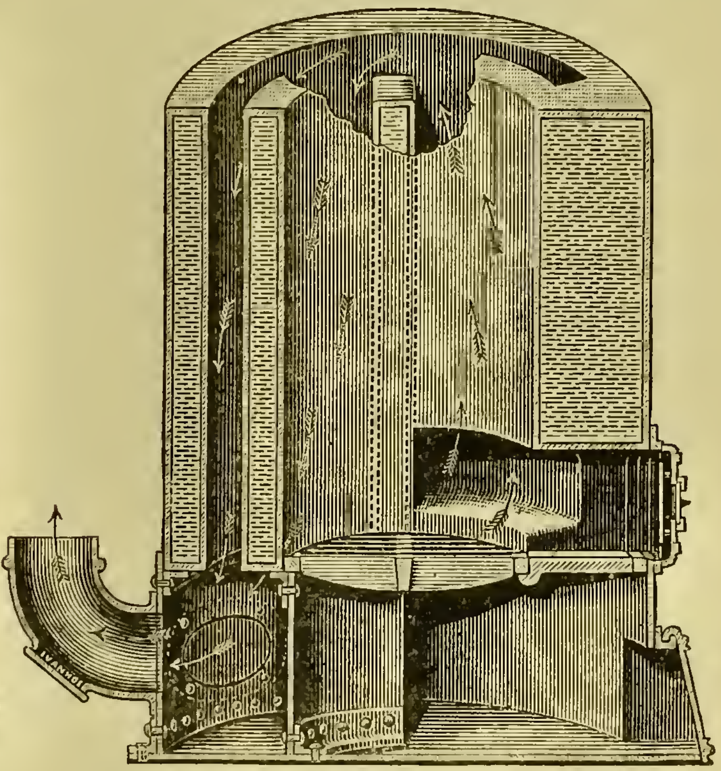

Fig. 132.—Section.

In the earlier part of this chapter it was mentioned that, hitherto, the use of independent boilers for large works (in England) was restricted by the limited number of boilers of this kind made in powerful sizes. Manufacturers are realising that the independent boiler capable of extensive work is needed, and Figs. 131 and 132 illustrate a new and good example.* This is a wrought-iron boiler with vertical waterways, consisting chiefly of an internal and external cylinder. The internal cylinder is conveniently arranged to take a charge of coke, fed from the top. The flue ways between the two cylinders are accessible by the semicircular covers shown on top of Fig. 131. The flame or heated products from the furnace of this boiler do not pass up through the overlying charge of fuel, but pass into openings on the right and left of the stoking door, these openings leading into the flueway between the two cylinders. The opening on the right of furnace door is shown in Fig. 132, the arrows showing the passage of flame up, over the waterway mid-feather, then down to the flue outlet, which is at the base. This boiler is made in ten sizes, capable of heating from 990 to 2850 feet radiating surface (actual power). It can be arranged for steam heating if desired.

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* Made by Mather and Kitchen, Derby.

As stated, cast-iron boilers do not receive the share of favour in England that they do in America, but English engineers are gradually losing what prejudice they had to them. Americans contend that cast iron is decidedly superior to wrought for heating boilers, whether water or steam, and, as their experience is so much greater than ours in these works, their opinions are worthy of every consideration. A wrought-iron boiler for this work is more rare in that country than a cast-iron one is in England, and the advantages they claim for cast iron are essentially practical.

Cast boilers are made in sections (except the very small sizes), so that the complete boiler is made up of parts bolted together. Where two or more parts have the waterway continued through them, then there are apertures in each section that correspond and come together when the bolting up is effected. One advantage of the sectional construction is that in the case of large boilers the parts are so easy of transportation. The boiler may be in eight or ten parts, which admits of its being carried into a basement quite easily compared to the trouble that occurs with an equally large boiler that cannot be taken to pieces. This is a very real advantage in many cases. Another is that by the addition of sections the power of a boiler can be increased or varied in a simple way, in fact, any power of boiler is quickly built up from a stock of castings. This, perhaps, is an advantage to the manufacturer more than the user.

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* The "Columbia" double cylinder independent boiler made by R. Jenkins & Co., Rotherham.

Perhaps the greatest advantage gained with cast iron is the perfect way in which the heating surfaces can be made to best advantage. With wrought boilers the surfaces have, necessarily, to be flat and plain, whereas with cast-iron they can be convoluted, ribbed, studded, or made in any way that ensures the best results from the fuel expended. Flues can also be more readily made, and many variations of heating surfaces practically impossible with wrought iron.

There is no doubt that a good casting will withstand heat, and the wear and tear due to heat, better than wrought iron ; and more especially so if the conditions are bad by collection of deposit or similar troubles. But supposing any part of a cast boiler should fail from any cause, the failure must be located in one section, and only this part requires attention. As a rule the renewal of a section can be effected by any hot-water engineer on the spot, and this is not such a serious happening as when a wrought-iron boiler fails. With the latter nothing can be done as a rule without removing the whole boiler from the premises, and as a failure always occurs when the boiler is in regular use, and wanted, the annoyance as well as the expense are rather great.

Fig. 133 is an example of a cast sectional boiler, the number of upper sections governing the power of the boiler. These upper sections much resemble gratings with waterways through the bars, and by this arrangement the heat is very effectively absorbed.

The very latest outcome of building boilers in sections is represented in the "Merton" sectional boiler, Fig. 134.* Hitherto it has been considered necessary that the sections should be directly connected, either coming together with true-faced joints, or being made water-tight one to the other

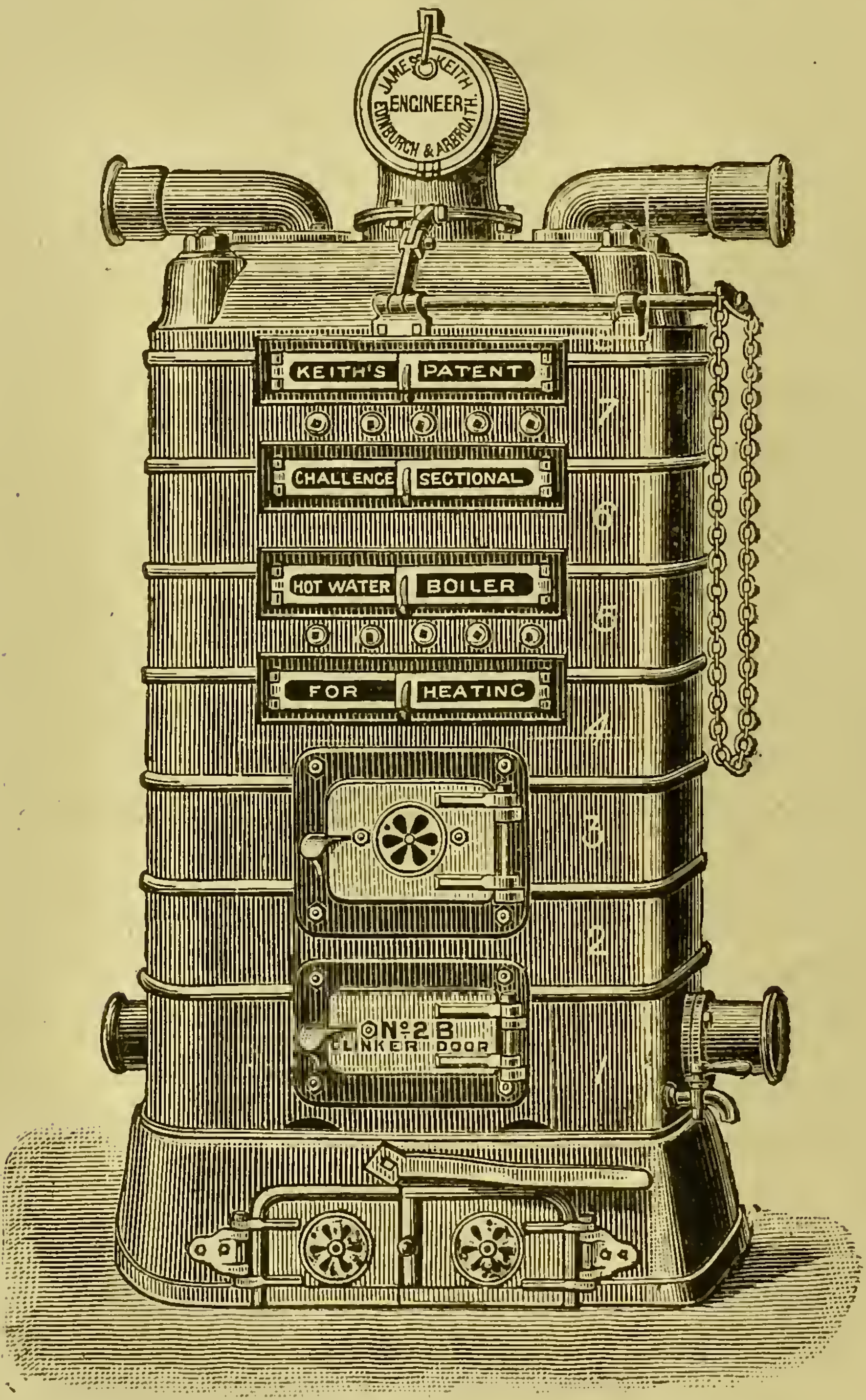

Fig. 133.

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* From the catalogue of Fredk. Dye & Co., 58 St. Paul's Churchyard, London, E.C.

by means of jointing material. In such cases there have to be corresponding apertures in the sections, so that the water can freely circulate through the whole, from the return-pipe connection at bottom to the flow-pipe outlet at top. The failure of a section then throws the whole boiler out of use, and should heat be needed at that time all that can be done is to obtain a new section, and effect the repairs with the least delay possible. This is, of course, much better than having either to renew the whole boiler or send it to the maker's works for repair, as would be the case with a wrought boiler, but with the perfected system embodied in Fig. 134, the leakage of a section is not so serious by any means.

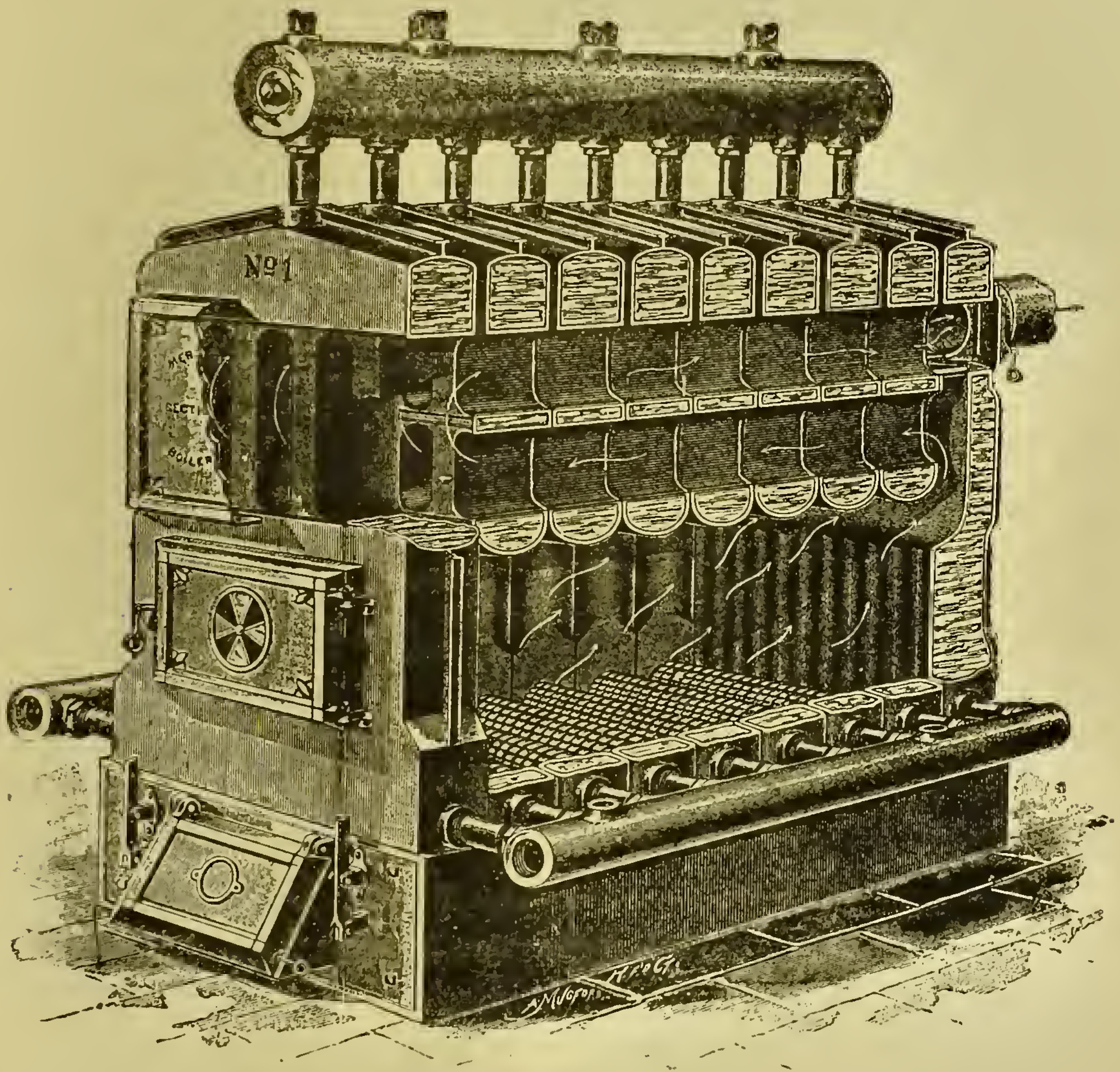

Fig. 134.

A failure, with boilers, always happens when it is most difficult to remedy. It does not occur when a boiler is out of use and can be spared, and it is in this fact that the principle of the "Merton" boiler has a great advantage. There is no direct communication between the sections of this boiler; each section is a boiler in itself, having independent connection with the flow and return headers or drums, as shown. Each section, therefore, has its water from the return drums by the connecting pipes shown, and delivers it to the flow drum above. In principle, the sections may be likened to a battery of boilers all connected with flow and return storage tanks, from which tanks the distributing mains proceed. In event of the failure of a section it is only necessary to disconnect it from the drums, plug the holes, re-charge the apparatus, and light the fire. Under ordinary circumstances this would not occupy more than two hours' time. The bad section is left in its place, empty and dead, its presence in no way interfering with the active work of the others. The boiler continues its work, one section less in effectiveness, until the new section is obtained and a convenient time has arrived to put it in place. The boiler illustrated is made in sizes to heat from 1200 to 5500 feet of radiating surface (actual power).

All sectional boilers are at an advantage in being easily transported and fitted up—that is, compared with wrought boilers—when the size is large. As a rule boilers have to go into very awkward places, in basements, &c., where the parts of a sectional boiler are quite easily got, not being too large to pass down a staircase.

Figs. 135, 136* represent the "College" boiler, also of cast iron, and this, as with the last, shows a full area of internal heating surface. In this the sections have direct communication, the limited size of boiler making any special arrangement in this respect unnecessary. It is made in sizes to heat from 300 to 1600 feet of radiating surface (actual). These cast boilers are fitted with mechanical furnace bars, and all parts are readily interchangeable.

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* Also from the catalogue of Fredk. Dye & Co.

With all cast boilers of the American type there is provided an ingenious arrangement, for controlling the draught, in place of the ordinary slide damper. The ash-pit door which admits, or closes off, the passage of air through the fire-bars, is pivoted at the sides, as shown with the boiler, Fig. 134. Some are pivoted centrally each side, so that a very trifling force is sufficient to make them lift open. In the flue-nozzle at the back there is also a door, or sometimes a pivoted damper, and on both these are provided eyes to receive a cord (the eye is shown on the ash-pit door of Fig. 134). From one to the other there is a light cord connected, this cord passing over a pulley secured in the ceiling above. By working the cord a very perfect control of the draught is obtained, as not only is the chimney draught acted upon, but the passage of air through the fire also,

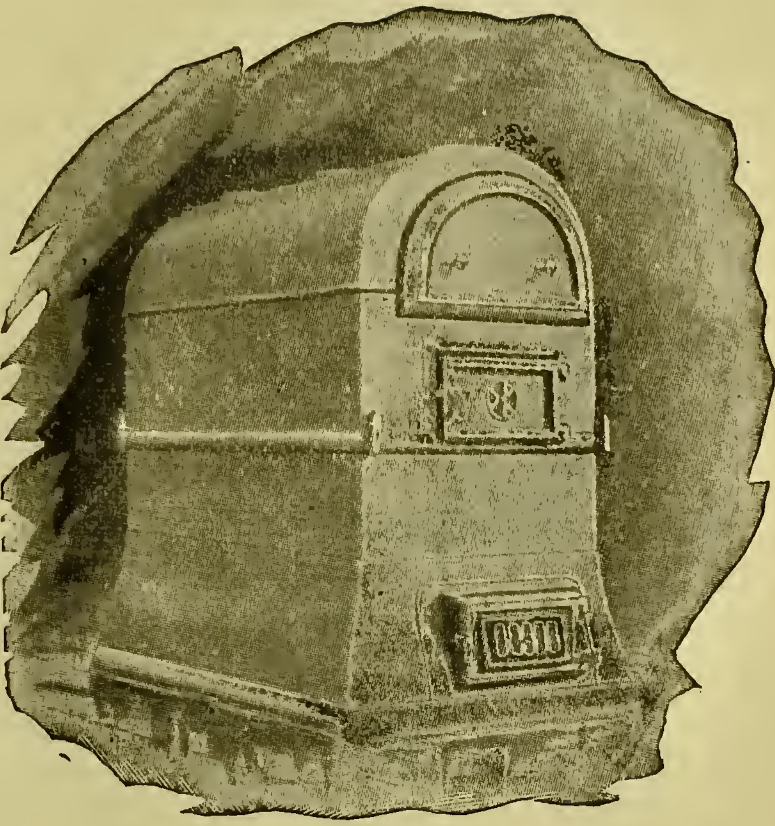

Fig. 135.

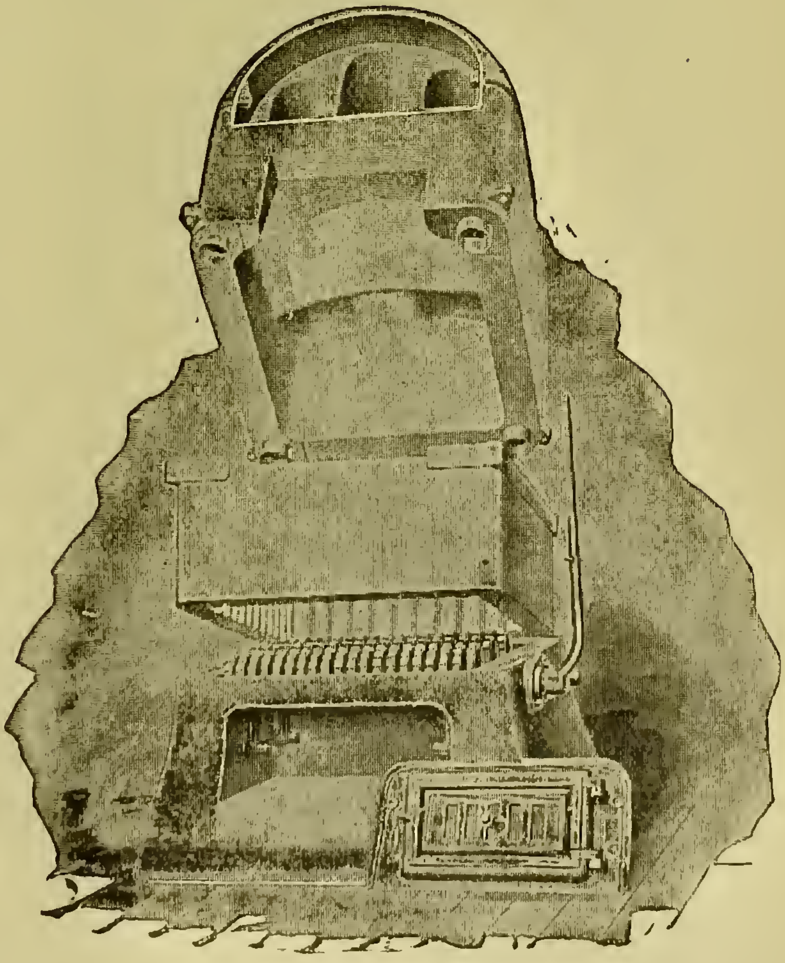

Fig. 136.

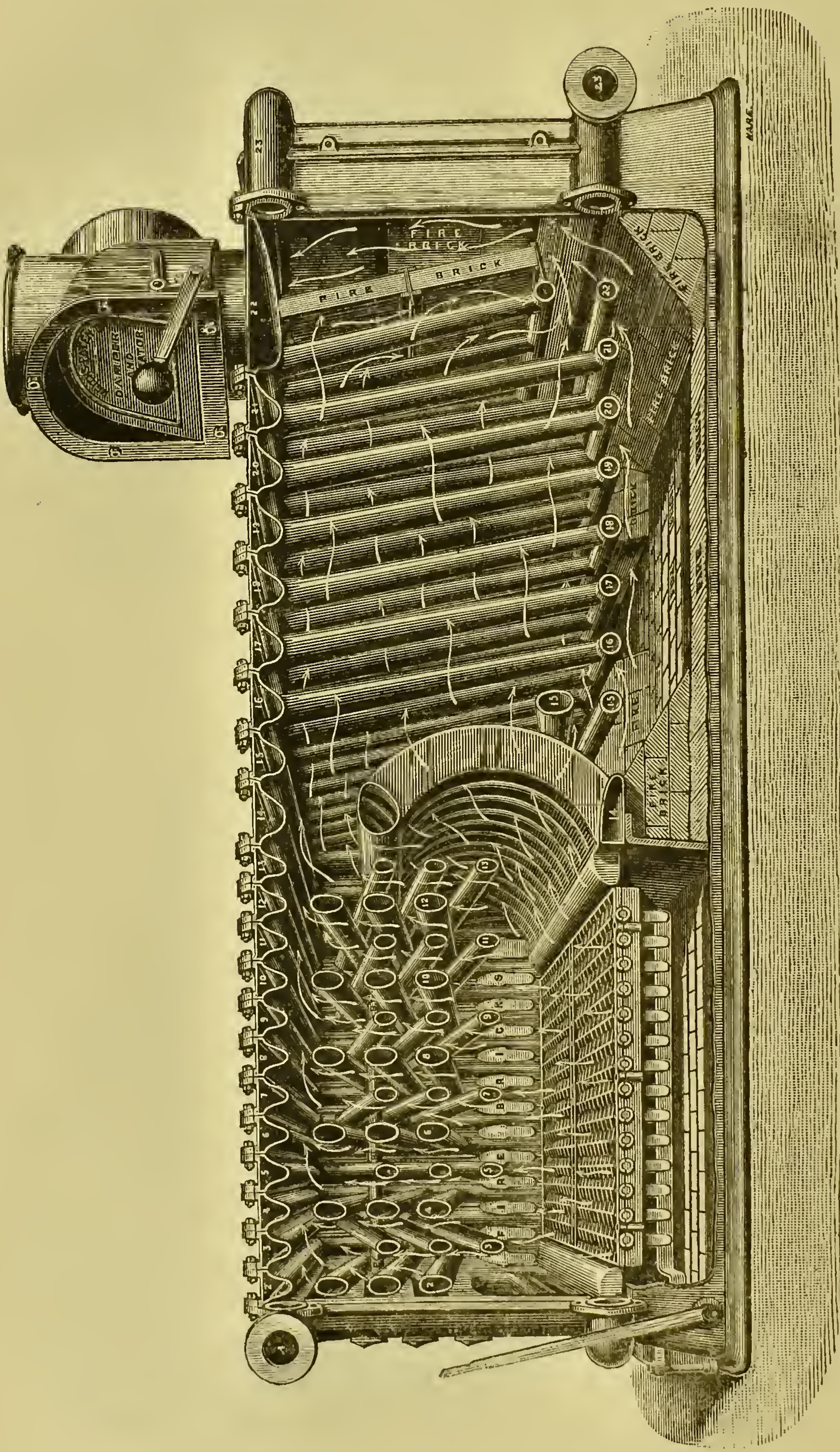

Fig. 137.—Keith's "Python" Boiler.
This is a cast-iron sectional boiler, each section consisting mainly of waterway tubes, as shown.

and simultaneously. All English boilers are provided with both these means of controlling the heat and combustion, but they are not arranged to be worked together in such a simple way. The real object of the arrangement with American boilers is to admit of the doors or dampers being worked by one of the automatic appliances of which they make and use several different kinds. These appliances are operated either by the heat of the water or the heat of a room. We have nothing of the kind made in England at present.

Fig. 137 illustrates what is probably the largest and most powerful form of boiler made for hot-water circulation. This is Keith's "Python," a horizontal sectional boiler, the name being appropriate as its length can be increased or contracted (by varying the number of sections). It is a cast-iron independent boiler needing no brick setting, though with such a large exterior water surface the loss of heat would be great if not prevented by covering it with a poor heat-conducting material.

With all cast-iron sectional boilers the interior construction is such as to make external flues unnecessary. In arranging the surfaces of the sections it is always planned that all useful heat may be abstracted before the gases and products of combustion can reach the flue nozzle, and this can be very effectually done. A greater efficiency is obtained in this way, and a boiler that does not require brick setting is always preferable to one that does. As soon as independent boilers are made fully effective and causing no waste of heat by the absence of external flues, so they will become more freely used for heating brick buildings. For horticultural works probably the brick-set boiler will continue in favour, though for no special reason except that it can be set in its brickwork very conveniently when the pit is being made.

Independent boilers may be covered with non-conducting compound, or brickwork, to prevent loss of heat, but no external flues are needed. The internal surfaces are sufficient to abstract all the useful heat from the gases and products of combustion.

CHAPTER XIII.

BOILERS FOR BRICK SETTING.

Saddle boiler and modes of setting it fully described—Water bars and connecting—Check ends and waterway fronts—Cross tubes—Flued saddle boiler—The "Colonial" boiler—The "Climax" boiler—The "Imperial" boiler—The "Delta" boiler—The "Excelsior" boiler—Wagstaff's sectional boiler—Water bars for coil and tubular boilers—Multitubular boiler—Water-tube boiler—The Trentham Cornish boiler, &c.

THE chapter just finished dealt exclusively with boilers of the independent kind, which require no brickwork in their construction or setting (unless it is desired to build them in a wall, or to jacket them with brickwork). It is now proposed to treat of those that are dependent upon the bricklayer for their erection, setting and subsequent efficiency. The independent boilers shown constitute but a small portion of the great variety that are made, but enough has been said to illustrate the features that may be considered essential and good or bad in them.

The boiler that must take precedence in the following list is the "Saddle," Fig. 138. This shape stands high in every one's esteem, for it has been tried in every conceivable way, and found satisfactory. Hood praised it at least twenty years ago, and it is in favour still; and very many, most in fact, of the new designs of wrought boilers introduced follow the saddle shape to a great extent, as will be seen as the chapter progresses.

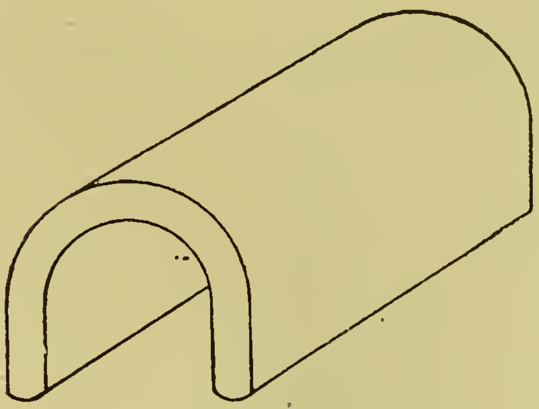
Fig. 138.

The particular features in favour of the saddle boiler are, that of all wrought-iron boilers it is about the cheapest to make; its shape is particularly adapted to receive and benefit by the heat evolved, especially the direct heat, which is the most valuable and effective. And it is found in practice that this shape is free from the faults that are brought to light from time to time with the many new patterns introduced. The saddle shape, however, is not usually adopted for works that exceed, say, 800 to 1000 feet of 4-inch pipe, for it is beneficial to bring the heating surface within a limited area, that it may profit fully by the heat radiated from the fire. This is effected by restricting the length and adding water-way ends, cross tubes, &c., which greatly increase the power of the boiler without increasing the size, as has been already explained. If a very long saddle boiler were used it would necessitate greatly increasing the length of the furnace area if the whole internal surface is to receive a full share of the radiant heat.

An instance in which the saddle boiler cannot be used is when the pressure of water is high. It is a boiler seldom seen put to heat high buildings, having the heating apparatus extending up three or four floors. The pressure of water in such a case would probably bulge the flat surfaces of the boiler, the inner plate being distorted the most. It may not actually burst the boiler, but the plates become misshapen, and a leakage will very likely occur. For high buildings the other more complex forms are used, and it is essential in ordering boilers to mention if the pressure is high.

From the illustration (Fig. 138) it will be noticed that from a point about half-way up the boiler, the top describes an almost true half circle, both outside and inside, but to the writer's mind greater effect would be obtained if the boiler was made more square in shape, so that the inner—the direct, and most valuable heating surface—would be added to, and the vertical flue surface would be increased. The vertical surface does more effective work than that which comes *beneath* the heated products, as is the case with all the outside rounded portion of the ordinary saddle boiler. Fig. 139 illustrates what is meant by making the boiler square in shape, and it will be readily seen that the internal and external surfaces are added to, and of course the quantity of plate used is increased proportionately. There is not the least doubt that the top outer surface of a boiler, whether it be round or flat, is of little value, as in the first place every one knows what little useful effect is produced by applying heat to the top of a vessel. And furthermore the top of a boiler of either shape always has a coating of dirt or soot upon it (except immediately after it has been swept clean), and this dirt material being always of a low conductivity, admits of very little heat passing through the boiler plate to the water.

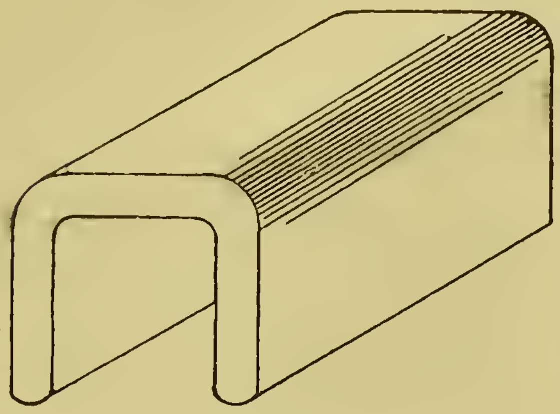

Fig. 139.

In the square shape of boiler the top surface could still be made use of if desired, but it must be contended that by placing the mid-feather half-way up the side of the boiler and causing the flame to travel to and fro along the side only, better results will be obtained than if any part of the side surface is neglected for the sake of passing the heated products over the top. With the shape under discussion the top need not be used at all (unless particularly desired). There is ample vertical surface for the heat, with an ordinary draught, to act upon, and every one must admit that however low a value vertical surface has, it is more valuable than any surface that comes beneath the source of heat, the source of heat in each case being equal. If, with this square shape, no use was made of the top outer surface, the cost and labour of fixing would be reduced to a small and simple affair, as no arch would be needed.

As before mentioned, the "saddle" boiler has always been found very effective and satisfactory for many general purposes, as it is free from complexity; and it is somewhat exceptional for it to be set wrongly, it having become so well known and used by all classes of heating engineers. The mere fact of the knowledge of its proper setting being so general has doubtless gone far to effect its recommendation, as many engineers, especially those who have no very extensive practice, are naturally somewhat shy of the newer patterns of which they have had no experience. But however much the "saddle" shape may be esteemed, it is not suited for large works, as for economical and rapid results we must have the direct heating surface as extensive as possible *close to the fire.* Or next best to this, have flues constructed within (i.e. through) the boiler itself where the heated gases can do effective work almost immediately they leave the burning fuel, and before they can have possibly lost heat.

There is more than one method of setting a saddle boiler, and for the smaller sizes it is doubtful if leading the flame to and fro the length of the boiler is so satisfactory as the following way, which permits the heated products to escape at all points around the boiler, and envelop it, so to speak.

This method is to have the furnace bars, dead plate and other fittings in their customary places, but instead of the boiler standing level with the fire grating it is placed upon four fire-bricks, one at each corner, forming four feet, which raise the boiler about 3 inches above the level of the bars. And instead of bringing the boiler tight against the front brickwork, and also partially closing up the back portion, it is simply stood so as to come within, say 1½ to 2 inches of the brickwork at either end, with a clear space of 3 to 3½ inches up each side and over the top.

Figs. 140 and 141 show the arrangement in length and cross sections, but the position of the chimney requires consideration, as it must always be remembered that the action of the draught induces the flame and heat to take the shortest or easiest route, should there be two or more ways unequal in length or size, by which it can pass. In the illustrations the chimney is shown built as near as possible centrally over the top of the boiler, and supposing it were situated exactly over the centre and the flue passages up the boiler sides were equal in size, the boiler would heat about equally all round. If, however, the chimney was not so situated, steps would require to be taken, by means of deflecting plates, to cause the flame to distribute itself generally in all directions as it passed away from the fire. This arrangement, however, is only suited for small boilers, and unless the circumstances appear very favourable the writer would not recommend this method as against the customary way of conducting the flame up and down the boiler side as next to be explained. It must also be pointed out, that when a fire has been going quietly for several hours there accumulates a quantity of ash on the fire-bars, and this would somewhat interfere with the free passage of heat to the outer or indirect heating surface of this boiler by choking the way along the bottom each side.

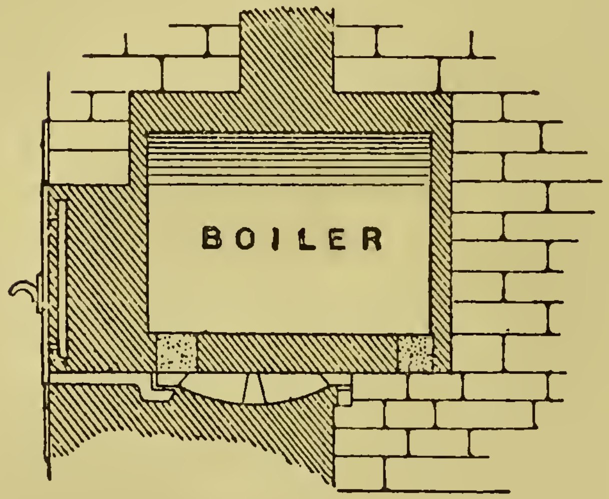

Fig. 140.

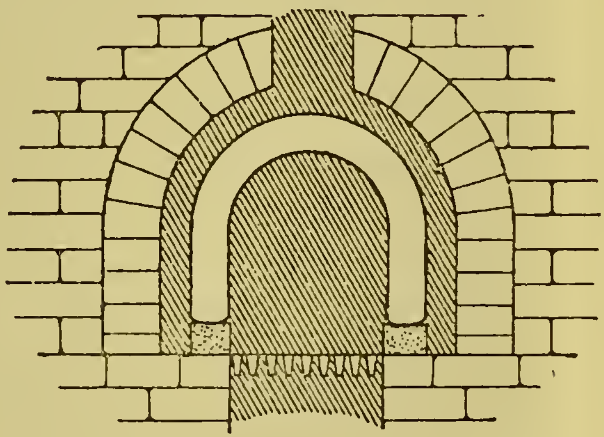

Fig. 141.

It will be understood that the reason for giving a 1½-inch space between the front and back ends of the boiler and the brickwork, is to prevent the flame having too free a passage in either of these directions to the prejudice of the outer side heating surfaces. If the chimney was situated at the back end of the boiler instead of centrally over the top, then it would be better to let the back end of the boiler butt tight against the brickwork, without any passage way being left at that point.

The most customary and, at present, the best way to set a saddle boiler of any size, is to provide flues passing to and fro along its outside as follows:—The boiler is placed upon a level with the furnace bars* so as to come tight up against the front brickwork, that which the front fittings are fixed against, making a flame-tight joint at this point, as Fig. 142.† This brickwork will be 9 inches thick. The furnace bars, in addition to having their upper surface on a level with the bottom of the boiler, are so arranged that the front extremities of the bars are exactly in a line, vertically, with the front of the boiler, the dumb or dead plate extending from the bars to the furnace door, as shown. This plate also comes exactly level with the furnace stoke hole, so that all the parts that

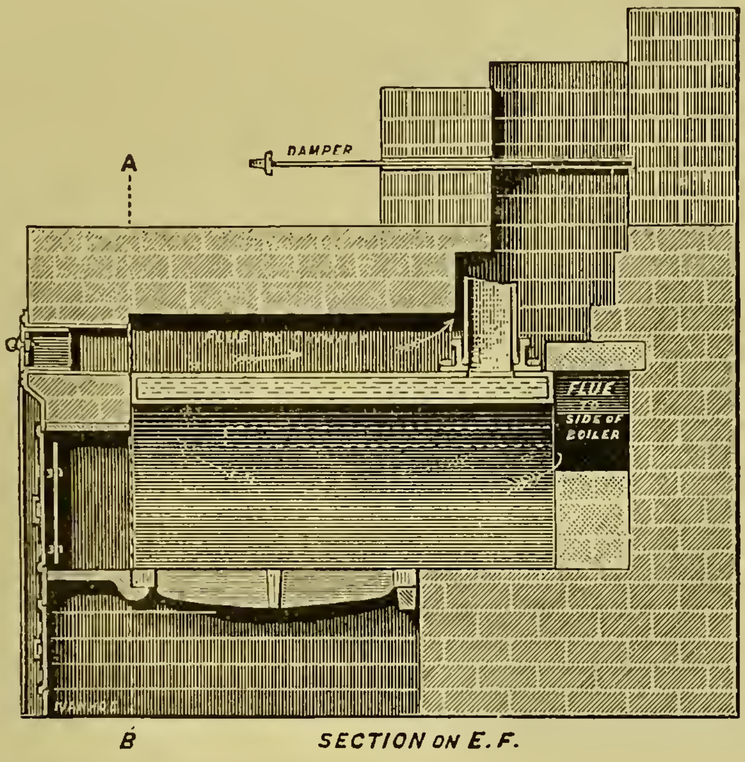

Fig. 142.

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* Any direction as to the height of the furnace bars is rather unnecessary, as the position for these is fixed by the make of the furnace fittings. The front, with fire-doors, and the other articles that constitute the set of fittings, are purchased complete from the boiler-makers or elsewhere, and show exactly where the furnace bars are to come.

† Furnished by Robert Jenkins & Co., Boiler-makers, Rotherham.

constitute the bottom of the fire-box, where the fuel rests, are on a level from end to end right through, as illustrated.

The bars usually occupy about two-thirds the length of the fire-box (see area of fire-bars, p. 201), resting at one end on the dead plate, which should be rebated to receive them, and at the other end on a bearing bar on or in front of the solid brickwork which extends from this point to the back.* The back end of the boiler does not come against the back wall, but is kept from 5 to 7 inches away from it, to admit of making the proper passage way from the interior of the boiler to the outer flues.

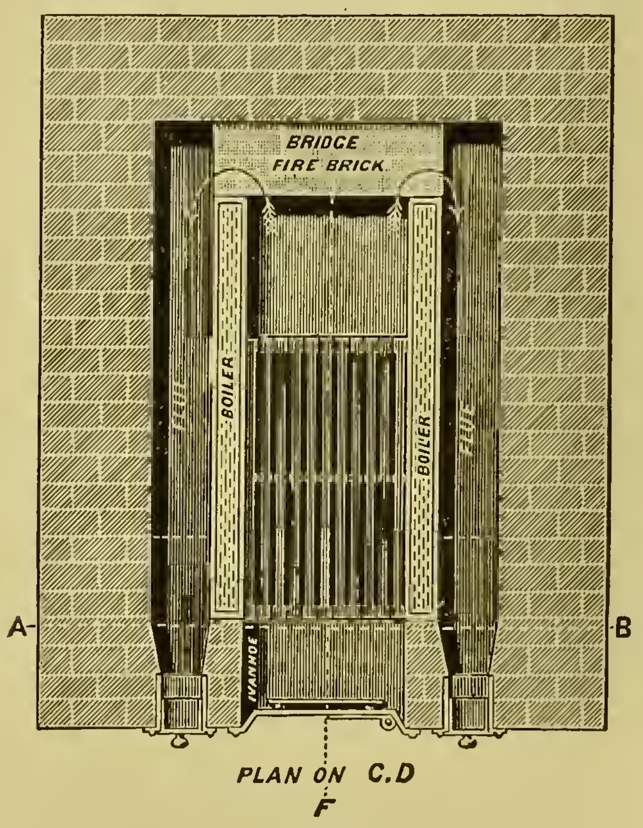

Fig. 143.

Between the boiler and brickwork at back is built a fire-brick bridge or check end (to check the too free escape of heat) extending from side to side as shown on the plan drawing, Fig. 143.† This reaches quite half-way up the arched opening in the boiler, as shown in the last illustration. With small boilers a thick fire-brick slab is occasionally used for this purpose. The bridge fulfils another useful object in forming a boundary to the fire-box, as were the side flues to have their entrances low down, the stoking of the fire would quickly cause them to get partially stopped with cinders and débris.

Above this check end another bridge has to be made, to prevent the exit of flame from the upper part of the arch into the upper flue above the mid-feathers. This bridge may be made with a large fire-brick if the boiler be of limited size, but usually it consists of an arch formed in fire-bricks, as will be fully explained directly. The illustration (Fig. 142) shows the direction the flames have to take, the arrow passing sharp round to the outside of the boiler, *below* the mid-feather, the position of which is indicated by the dotted lines.

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* The furnace bars are always kept forward, so that the whole of the direct heating surface may have the full benefit of the heat before it passes to the flue entrance.

† This bridge usually extends right to the brickwork each side; nothing is gained by keeping it just the width of the boiler.

Fig. 143 * shows in plan (at a point just below the mid-feathers) the position of the lower fire-brick bridge, with arrows showing how the flame and heated products pass to right and left around to the outside of the boiler within the flues referred to. The extent of the side flues, the position (in plan) of the two lower soot doors, the fire-bars, the dumb plate, &c., are also clearly shown.

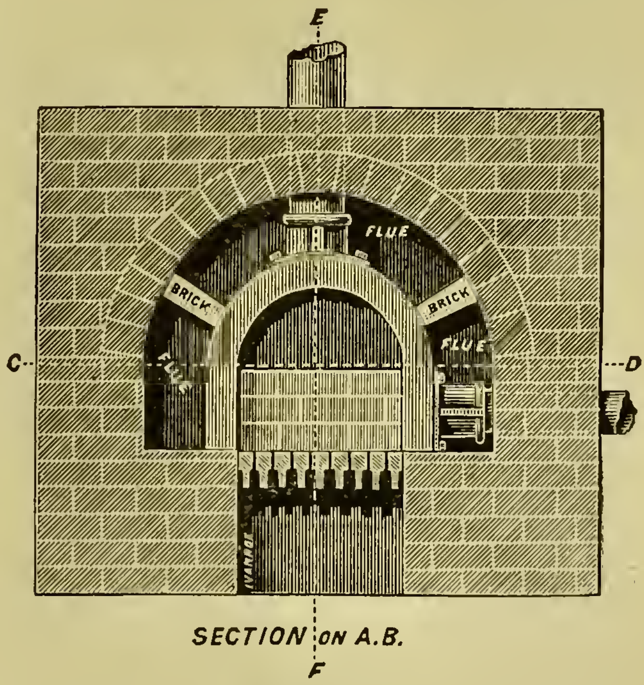

Fig. 144.

Fig. 144 shows the same boiler in sectional elevation, the section being across the front of the furnace bars. It will be noticed that the brickwork forming the bottom of the side flues is also on an exact level with the bars, so that at the moment the fixer is about to place the boiler in position, the erection, as far as he has proceeded, is about 12 inches high, and perfectly level from side to side and from end to end. At the back end of the boiler will be seen the bridge already referred to; the flow pipe proceeding from the top and the return entering the side are also shown clearly. The return pipe can of course be brought in either side, or one in each side if desired, but the position of the return pipe will be further referred to directly.

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* Also furnished by Jenkins & Co.

The most important features in this illustration are the mid-feathers, and the arched flue-way which the two mid-feathers divide into three parts. These drawings are not to scale, so no accurate result can be arrived at by comparing any portion with the size of the bricks of the brickwork, and it will be noticed that the flow pipe, assuming that it is 4-inch, is out of proportion with the size of the boiler. This is merely mentioned as it is so customary and natural to judge approximate dimensions by comparison. The flue-way, at sides and top of boiler, as here shown, and which appears on the other drawings, must be of a proper size (width). If too small it will choke the passage of flame, and with coal fuel it would soon be stopped with soot; if too large, the flame or heated gases will not have their full useful effect, for (as already explained) flame has a most pronounced tendency to float between surfaces without having contact with them when it is possible. As flame radiates but a very small amount of heat, it is necessary that it should be made to impinge on or have contact with the parts to be heated.

When the flame leaves the interior of the boiler at the back, the direction in which the draught impels it to travel makes it hug, or cling to, the sides of the boiler, so as to neutralise to some extent the inclination which flame has to avoid contact with surfaces; but notwithstanding this, if the flue were too wide little contact would take place. When the flame ascends from the side flues, in front, and passes into the flue over the top of the boiler, the flame, following its natural tendency, is inclined to seek the highest point and does more towards heating the top brickwork than heating the boiler top.

All these arguments go to show that the flues must be restricted in size, and as a general rule 4½-inch is the average size that should be adopted.

This width is subject to variation to some extent as the boilers vary in size. 4-inch or even 3-inch would suffice for the smaller boilers, say less than 3 feet long, and in those of large size a 5 or 6-inch flue would be better suited. It may be considered that the majority of plain saddle boilers that are made measure between 3 and 6 feet in length ; many are of smaller and larger sizes than this, but they do not represent the majority by any means, and between these two sizes a 4 to 4½-inch flue is suitable.

The mid-feathers extending from the end of the boiler to within about 6 inches of the front, as shown by the dotted lines on Fig. 142, can be made of fire-brick, iron plate, or, if desired, the boiler maker will make a waterway through them, as Fig. 145. They are most commonly made of fire-brick, as if iron is used it should be affixed to the boiler by the maker, which may cause delay. It is quite possible to support an iron mid-feather from the brickwork, although it is not such a satisfactory job as when secured to the boiler. The waterway mid-feather adds to the total efficiency of the boiler, but it is doubtful whether the gain effected is in full ratio with the increased cost. If waterway mid-feathers are used, it is very necessary to order them to the position required, otherwise they will be most probably placed as at Fig. 111, which in the writer's opinion is not so good as placing them as Fig. 144.

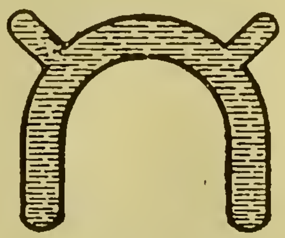
Fig. 145.

The position of the mid-feathers, i.e. the height at which they are placed, needs to be considered with the view of getting the best work from the fuel expended. It has been most commonly the practice to place these feathers at right angles to the sides of the boilers at the point where the curve commences, as at Fig. 111, just referred to ; but the ultimate effect can certainly be increased by placing them higher up. This gives more surface for the heated products to act upon immediately they leave the fire, instead of devoting more space to the top flue, where the heat does less work, and is to a great extent expended when it reaches there. In the illustration now under discussion (Fig. 144) the feathers are shown fairly high, but they might advantageously be placed just a trifle higher than this, as Fig. 146, so as to leave the top flue barely larger than each side flue. This will have a judicious choking effect to the top flue and help to bring the heat into more effectual contact with this surface. The heat commonly escapes to a great extent by reason of all heated gases having a tendency to keep clear of surfaces beneath them if there is sufficient room to permit it.

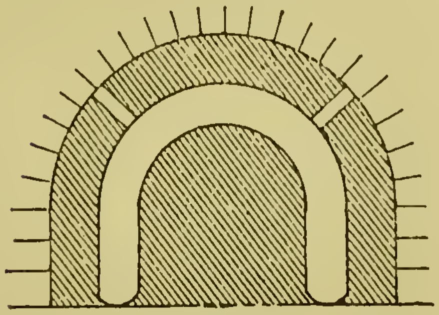

Fig. 146.

Occasionally a workman will be found carrying the front end of his mid-feathers down a little way at right angles, as Fig. 147; this has a good effect in causing the flame to spread itself more over the side surfaces. With a high mid-feather, the flame and gases always seeking the highest possible point, the draught will take the very shortest and nearest passage it can to reach the chimney. This prevents the lower portion of the boiler sides being fully acted upon, as the flame will be found to pass rather closely under the mid-feathers if this turned-down portion does not exist. Of course this improvement is not a necessity, but an improvement it really is, and adds a trifle to the total efficiency. The feathers must not be turned down very far, or they will interfere with the proper cleaning of the boiler (flues) outside, which is particularly necessary if the fuel, or any part of it, is coal.

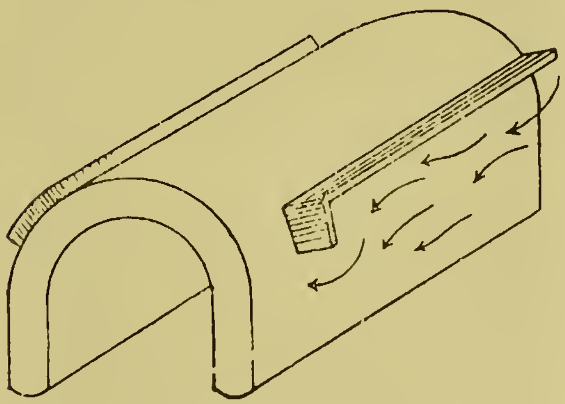

Fig. 147.

Before leaving these side flues it is desirable to point out that there is a point at which the return pipe (or pipes) should enter so as not to cross the flue and be an obstacle to the soot or flue-raker. Secondly, not to be a means of checking or reversing the circulation, as putting the return pipe in a highly heated place would be likely to do. The point referred to is low down in the side (as usual) at the back. At this point the return pipe can be neatly covered with brick and cement work, as Fig. 148; this obviates both the objections named. Nearly all boiler makers' illustrations show the return pipes connected into the middle or towards the front, but the back is decidedly the best in every way, as it does not block the flue. If Fig. 144 is referred to, it will be seen how awkwardly the return pipe would be placed, if we suppose it to be brought in anywhere near the front.*

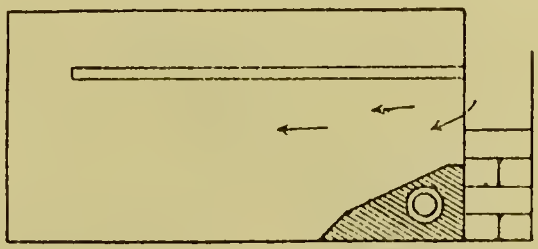

Fig. 148.

The arrangement of flues at the back of the boiler has already been referred to, but it is necessary to deal with it further, so as to make it clear how this part of the setting is carried out, for it is perhaps the most difficult point to those who have no experience. It has been explained (p. 238) that, in addition to the fire-brick bridge, which reaches from the bottom to about half way up the back of the boiler, there is another bridge carried across just above this with the object of stopping all passage of flame directly into the chimney above, and so causing it to pass around to the sides of the boiler beneath the mid-feathers.

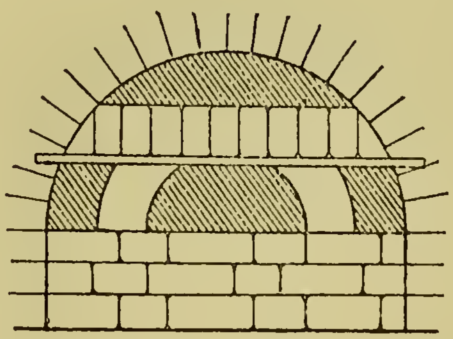

Fig. 149.

The construction of this upper bridge requires both care and skill, as although it is a common practice to carry this brickwork straight across, supporting it on iron bearing bars, as Fig. 149, this in the end is very commonly a bad arrangement. The bars must some day, sooner or later, be affected by the heat and gradually give way, and by this gradual collapse, choke, and eventually stop the passage-way between the two bridges in question. Hood recommended a solid fire-lump for this purpose, as Fig. 150, which is his original illustration of the back of the boiler with the bridges *in situ*. Fire-lumps, however, are hardly practicable for large wide boilers, on account of the expense or difficulty in getting them when the work is away from large towns (as it commonly is). The upper bridge can be better made of fire-bricks, without a bearing bar, by making it arched, as Fig. 151. This arch should commence on a level with the feathers, these being brought right through just below it to as far as the back brickwork; and supposing this arch bridge to rest on the edge of the feathers, as this explanation suggests, then they must be well supported by brickwork gathered out from the back, as Fig. 152. It will be noticed from Figs. 151 and 152 that the top of this arch-bridge is level with the top of the boiler; this permits the top flue to pass right over it, supposing the chimney to be quite at the rear; but when the chimney

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* It is desirable to keep the flow and return pipes as far away from one another as possible, as this prevents to a great extent collections of sediment, and other objections to be explained directly.

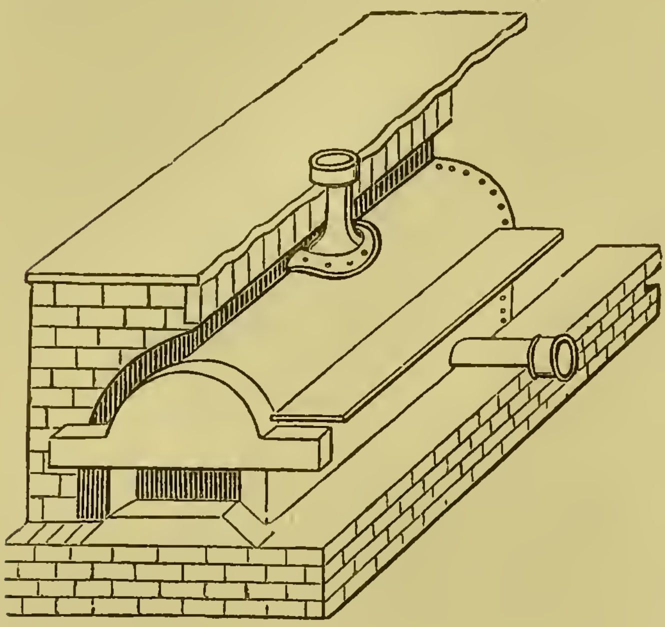
Fig. 150.

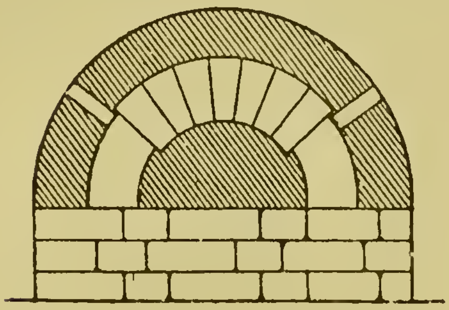
Fig. 151.

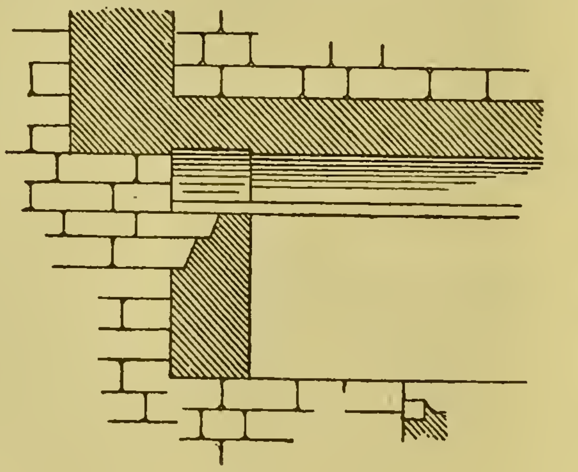
Fig 152.

starts away from the top, as Fig. 142, this bridge is sometimes carried over, resting on the edge of the boiler, as is shown there. A little better joint between the boiler and brickwork is effected this way, but it is not the best plan if the chimney starts upright at the back, although it could still be done then. In this drawing, Fig. 142, the bridge in question is made by bricks placed lengthways from front to back, about 1 inch resting on the boiler and 2 inches in the brickwork at the back. This leaves a 6-inch space, which is sufficient with moderate sized boilers, but it might advantageously be made 8 inches in the larger sizes. Roominess at this point, from front to back, is desirable; at other points it is objectionable, as explained.

The pit in which the boiler is situated (if a pit is required) can be either of brickwork or concrete, and sometimes they are lined with iron, but with none of these materials can the pit be kept dry if the drainage is shallow; that is, if water is found in the earth at a higher level than the bottom of the pit. This necessitates the use of special shallow boilers (see p. 252) unless the house which the boiler is to heat is by some unusual circumstances raised up somewhat. In any case, every effort should be made to drain the pit, as even with good ground water may find its way into the pit from various causes, and as the pit is very commonly in an exposed place, provision to shelter it from rain and general inclement weather must be made.

In building the pit it must be made of such a size as to admit of the stoking tools being used freely, although shift could be made as regards this if absolutely necessary. The size of the pit is governed by the size of the boiler, and on this account, if the situation of the pit is peculiar, thought must be bestowed upon what space the boiler may be allowed to occupy. A "blow-off" cock for emptying purposes must be provided from the boiler in the pit, and, as explained, the plugged pipe ends should appear in front, see Fig. 114, so that the accumulated sediment in the boiler can be disturbed with rod or cane inserted through these pipes.

Fig. 153* shows the front in a finished state, with sweeping doors opposite the two side and the top flues, the flow and return pipes, and the damper in the chimney in place.

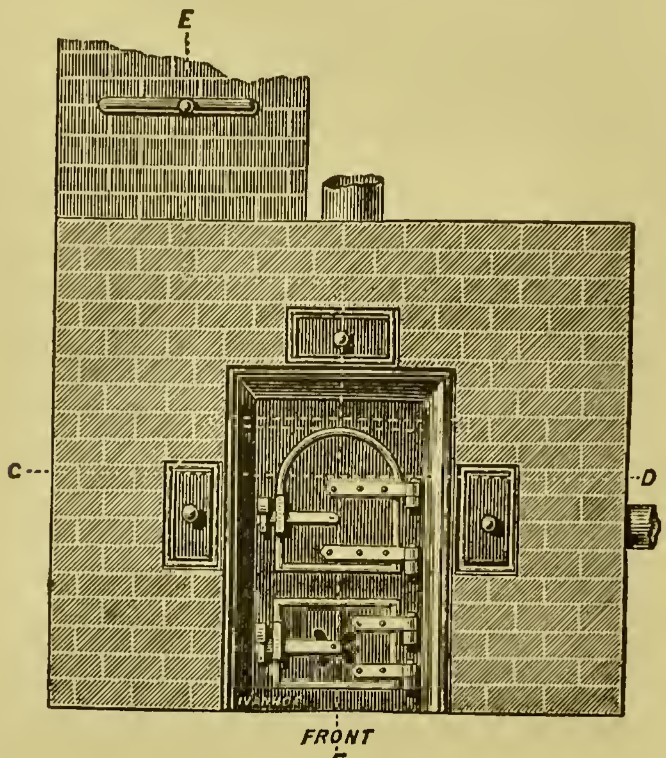

Fig. 153.

All the brickwork that is acted upon by the flame and heat should be built up in good quality fire-bricks. The other brickwork that is not directly acted upon by the heat can be of the ordinary character. The arch that is carried over the top of the boiler, corresponding in radius with the boiler top, is very commonly made by first building the sides up to the mid-feathers, then, after fixing these in position, the boiler top is covered with ashes or dry earth to a depth that the flue is to be, say 4½ inches. The bricks are then carried over, resting on this material, which is afterwards raked out when the brickwork has set. This is a most simple way of making the arch without the use of special appliances.

The iron furnace front is secured to the brickwork by clamps, but inserting these in the ordinary way is not always sufficient to keep the front soundly secured, the general effects of the heat tending to loosen it. Some fixers will have clamps extending from the furnace front, right through and clipping round the rear end of the boiler; this usually makes a good job of it. It can be taken as fair evidence of skilled workmanship if the furnace front keeps sound and tight against the front brickwork after the boiler has been in use a little time.

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* This illustration does not show the cleaning plugs that should appear in front.

There are variations to the method explained for setting saddle boilers. Some engineers consider that better results are attained by first carrying the flame over the top of the boiler from back to front immediately it leaves the interior, and causing it to descend and pass along the sides under the mid-feathers to enter the chimney. This arrangement has merits probably, or it would not be resorted to; but the writer has not discovered them, and certainly the results cannot be so satisfactory as by the method which has been fully explained, and which has by far the major share of approval. The particular objection to it in the writer's eyes is that it devotes the best services of the flame and heat to the top of the boiler, where it has the least useful effect, even supposing it was kept scrupulously clear of ash, dust and such matters.

Sometimes a workman will bring the mid-feathers right up to the front end of the boiler, and make provision for the flame to pass from the lower to the top flue by a recess in his front brickwork opposite the feather ends. No particular gain results from this; if anything it interferes somewhat with the removal of soot or dirt from the top flue unless other soot doors are provided, it being swept down into the lower flues in the usual way.

It was explained on p. 238 that from the lower edge of the furnace door right across the fire-bars to the back was an exact level. This is not always the case, as sometimes a fixer will make the dead plate slope down towards the fire-bars, so that the bars and the bottom of the boiler resting upon them are below the bottom edge of the furnace door, perhaps three inches, reducing the height of the ash-pit to this extent. This arrangement is usually resorted to only when it is desired to keep the boiler as low as possible, or, in other words, to work in the shallowest pit that can be used efficaciously, and for this purpose the method is a good and practical one.

The chimney, if brick, should not be less than 9 by 9 inches (inside) for moderate sized boilers; for the largest sizes 14 by 9 or 14 by 14 is desirable. A very common error is fallen into in making chimneys too small; this subject will be dealt with fully under Chimneys on a later page.

There remains to be mentioned that occasionally it is desired to use water-bars to the furnace instead of the ordinary solid bars; and in this case the return pipe or pipes do not enter the boiler at all, but enter the box end of the bars in question, and from thence circulating into the boiler, as here shown (Fig. 154). These bars keep more free from clinker than the ordinary solid bar, as they are always kept at a lower temperature by the water within them. They add to the heating surface to a fair extent, though not so much as would be the case if they were always clear of ash, which, however, cannot be expected. Commonly, the return pipes are brought into the front box end of the water-bars, as shown, and this is the best; but, instead of then bringing the connecting pipes into the front end of the boiler they might just as well enter the back,* so as to be no obstacle in cleaning the flues. The pipes forming the bars are cast much stronger and heavier than the pipes used for radiating purposes; they are also smaller. They cannot be cleaned out; their strength, however, goes far towards saving them

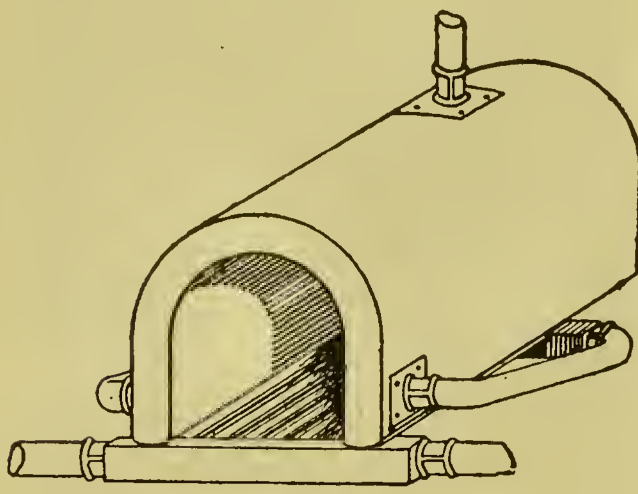

Fig. 154.

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* The positions that the flow and return sockets occupy on nearly all illustrations of boilers in the makers' lists, is the flow near the back end and the returns near the front, the contention being that this arrangement causes the water to circulate more uniformly through the boiler, entering one end and passing out at the other. The contention is a good one, as it will prevent as much as possible large accumulations of sediment occurring in certain parts of the boiler, and it will also prevent any violent internal circulations taking place. For general purposes, however, it will be found better to have the returns entering the back and the flow off the front at top, as already recommended.

from ill results, even supposing they became solid with deposit.

The first improvement on the saddle boiler was in making it with a waterway check end, as Fig. 155. This was a decided gain by adding considerably to the direct heating surface, and also to the flue surface at a point where the heat has its greatest effect after leaving the fire-box. This in no way affected the labour in fixing, except to lessen it a trifle, and the cost is increased to but a reasonably small extent if we compare one of these with an ordinary saddle of similar power (not similar size).

The effectiveness was further increased by putting a waterway front to the boiler (as well as a waterway end), as Fig. 156, but this introduced a new feature that had to be provided for—viz. the inability to attend to the fire at all successfully from the front, as the furnace door gave but little access to the fire-box, except for raking out. A door for feeding or banking up had therefore to be placed elsewhere; it is best if put in the top, as shown at Figs. 111 and 128.

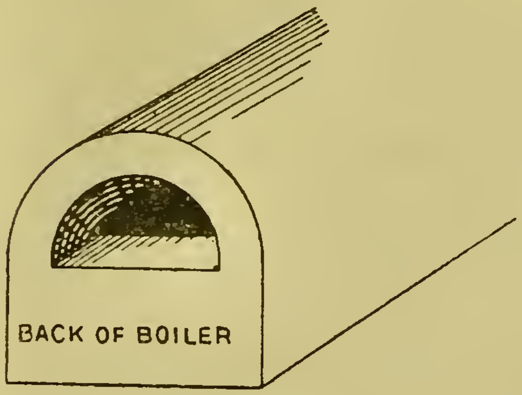

Fig. 155.

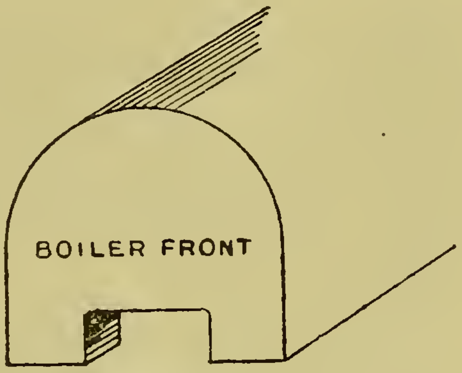

Fig. 156.

This form of boiler is in character with Hood's standard of efficiency, and even at this moment it is considered, and worthy of being considered, good, and capable of giving good results. There have been, of course, many new features since introduced that go to increase efficacy without materially increasing size.

Perhaps one of the earliest ways of adding to the effectiveness of a boiler of any description (saddle, Trentham or vertical) was the addition of one or more cross tubes, as Fig. 157; these are wholly direct heating surface, and being in, or nearly in contact with the glowing fuel, a very decided gain in heating efficiency is effected. This can be readily judged from a maker's catalogue, in which one size of this boiler is stated to heat 1050 feet of 4-inch pipe, and a plain saddle boiler to heat this same quantity requires to be one-third larger than the other. It is, however, not particularly desirable to introduce these cross tubes unless it becomes from some cause necessary. For small works it is better to have a plain boiler, the cross tubes being merely one of the different devices for adding to the power of the boiler without making it of unwieldy size.*

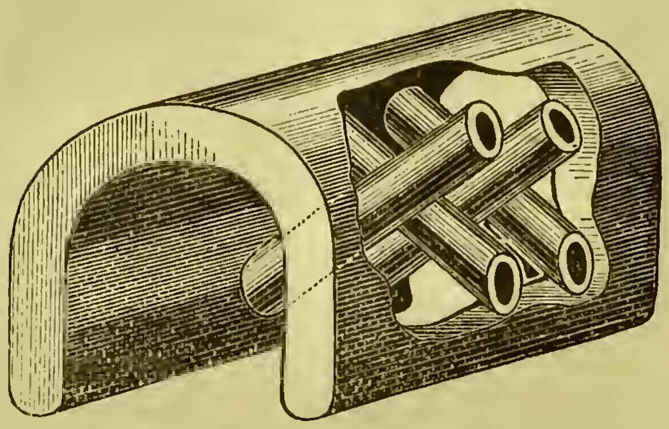

Fig. 157.

Fig. 158 shows a further addition to the saddle boiler in the top flue-way, which is within the boiler itself. This does not come within the category of the top flues deprecated by the writer when speaking of the value of flue surfaces, and again later under the heading of Saddle Boilers. This top flue allows of the flame and heated gases coming *beneath* a water surface, and by this means we get the most efficient of all flues, giving better results than vertical side surfaces.

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* If the writer is found to speak more favourably of one boiler than another, it is not intentional; all the boilers being noticed have some good features of their own, and none are introduced that have been found defective or practically weak. It also needs to be mentioned that no one can safely recommend one boiler to the exclusion of all others, as many of about an equal degree of efficiency are made, and, consult as many authorities as you will, they will all differ to some extent as to the merits of different kinds. Again, architects and engineers who have to deal with heating works, have different ideas as to what should be specified, some going so far as to design new boilers for their own purposes. All these differences in opinion of course account for the great variety of boilers that are now put upon the market. It is also peculiar that certain patterns will occasionally be sought after very greatly for a short time and the demand then cease, and some other pattern have the increased call. Certain patterns, furthermore, are favoured in certain localities.

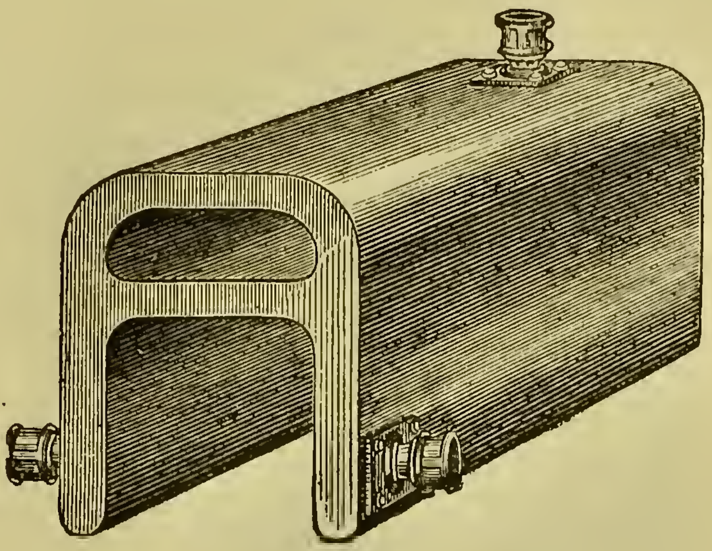

Fig. 158.

Several makers' lists show this boiler in section with the flame travelling through this flue from back to front, and then passing from the front *over the top* of the boiler to the chimney, as Fig. 159,* the object of the illustration (in the catalogues) being to show the method of fixing. Now, with an ordinary draught in the chimney there is no objection whatever to carrying the flame† down from the front and back along the two sides, using vertical feathers, as Fig. 160. This is decidedly more effective than carrying the flue over the extreme top of the boiler. Fig. 160 shows a similar boiler to the last but with waterway front, necessitating the top feeder, as shown. It must not be forgotten in setting these to provide the sweeping doors opposite the flues, as described with the saddle boiler, and one is

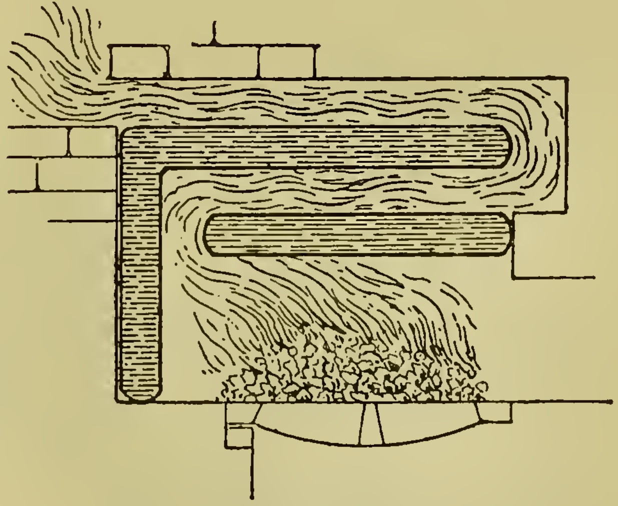

Fig. 159.

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* This boiler is made with or without a terminal end, but the former is much to be preferred, as illustrated.

† The word flame is used very freely, and it is feared in instances where it would be literally incorrect ; but it is a more convenient word than "heat" or "heated gases," when dealing with flues, even though it may apply to a furnace burning coke and producing no actual flames.

particularly needed opposite the top flue-way through the boiler, as this flue will have dusty matter deposited in it from coke, or soot from coal. The boiler just illustrated has a large demand, as it is very powerful, and has no objectionable features; it is also well suited for shallow drainage, and is economical of space for the results attained.

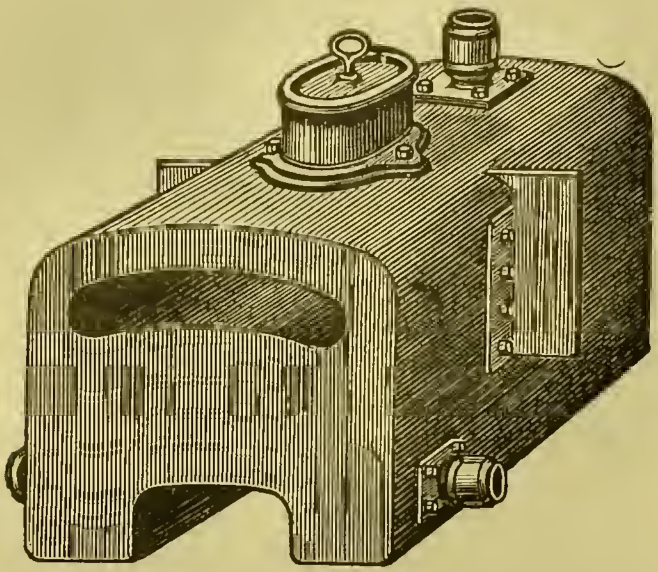
Fig. 160.

Fig. 161* is another powerful boiler, resembling in some respects the last one, but having twin flues at top instead of the wider single one. A peculiar feature in this boiler is the pieces stopped out of the front termination of the top flues, which permits of the boiler being butted tight up against the brickwork in front, thus decreasing in a considerable degree the labour in fixing. The brickwork is also brought down close to the top, the top surface not being used (the makers recognising the uselessness of this surface). Fig 162 shows in section the simple way in which this boiler is fixed. The necessary soot doors must not be forgotten.

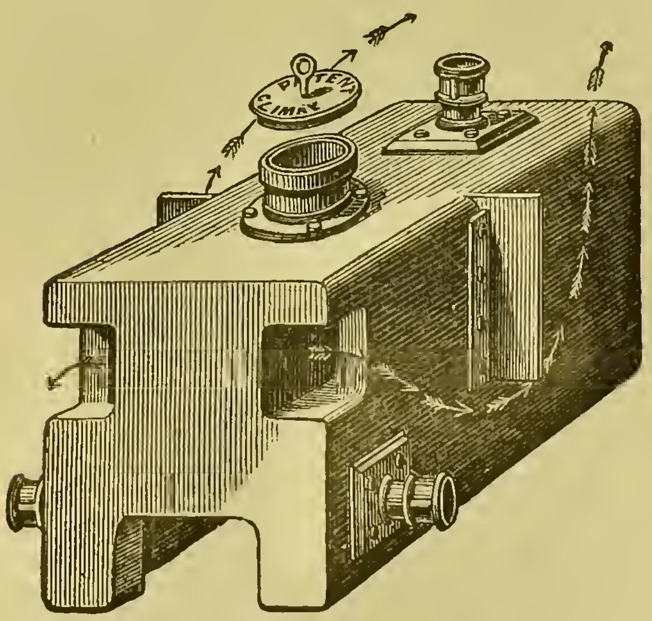

Fig. 161.

Fig. 163† is another boiler of a powerful character, and adapted for shallow drainage. From the illustration it will be noticed that the flame is carried both to and fro in flues within the boiler, and then to and fro along the outside as shown by the mid-feather. This necessitates having a chimney with a stronger draught than the preceding.* Fig. 164 is a transverse section of this boiler, showing its internal shape and also the method of setting. The flame when it leaves the fire enters the two lower side flues without leaving the boiler. From these it is caused to enter the top flues at the front, and from these top flues it is conducted outside at the back, passing under the mid-feathers, then back over the top.

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* The "Climax." Hartley & Sugden, Atlas Boiler Works, Halifax (England).

† The "Imperial." Graham & Fleming, Premier Works, Halifax (England).

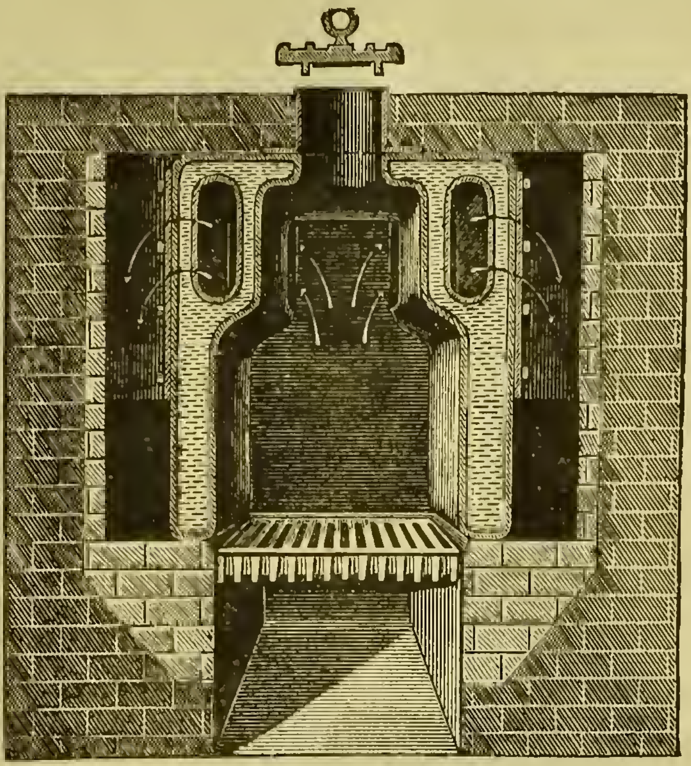

Fig. 162.

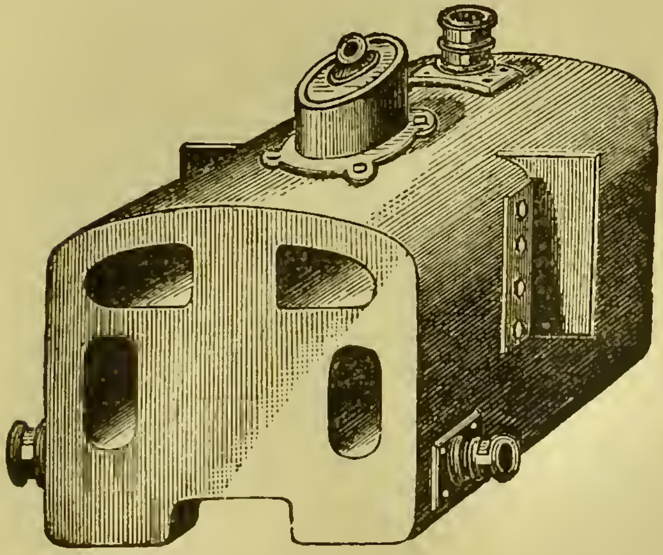

Fig. 163.

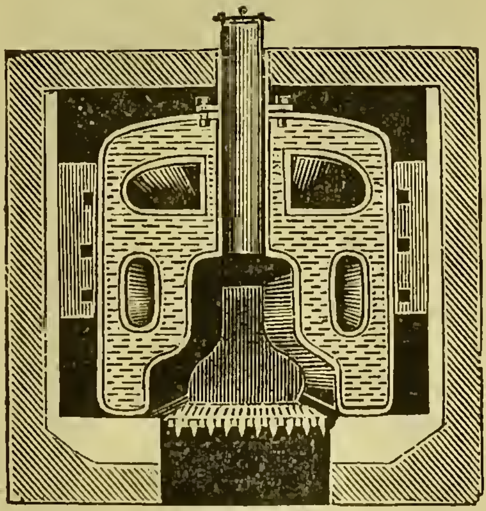

Fig. 164.

Perhaps the shallowest boiler at present made for difficult drainage is as Figs. 165 and 166,* its power being obtained by the increase in width instead of height. This is a terminal end boiler, and the arrangement of the flue-ways at the end causes the flame to impinge upon the upper surface immediately beneath the flow pipe. This must more effectually induce circulation when the apparatus is first started, and at any time a good result is attained by causing flame or heated products to impinge and come in contact with the boiler plates. This is the object of the "bridge" which appears inside horizontal cylindrical boilers.

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* A taller chimney, see Chimneys.

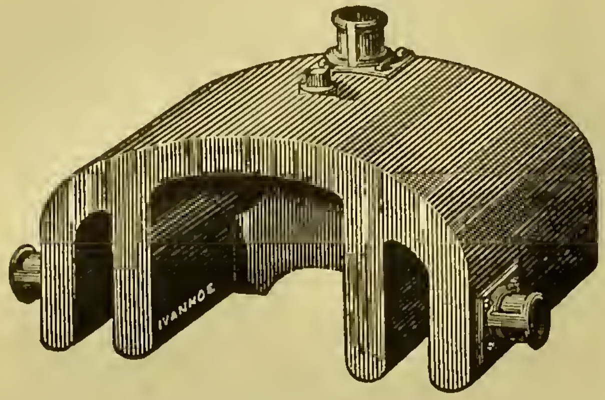

Fig. 165.

This must close the list of horizontal plate boilers. Sufficient variety has been shown to make clear the general features that at present exist in these, and although a large number of other shapes would be found if all the different makers' lists were collected, there is a great similarity in the majority of them to some of those just described. We can therefore now describe those that have some peculiar and novel features, and which entirely differ from those just treated, which are generally recognised as ordinary boilers. It must never be overlooked that the greater the length of horizontal flues the higher the chimney must be, and the more the flues turn to and fro the greater strength of draught and corresponding height of chimney is needed. This is often of

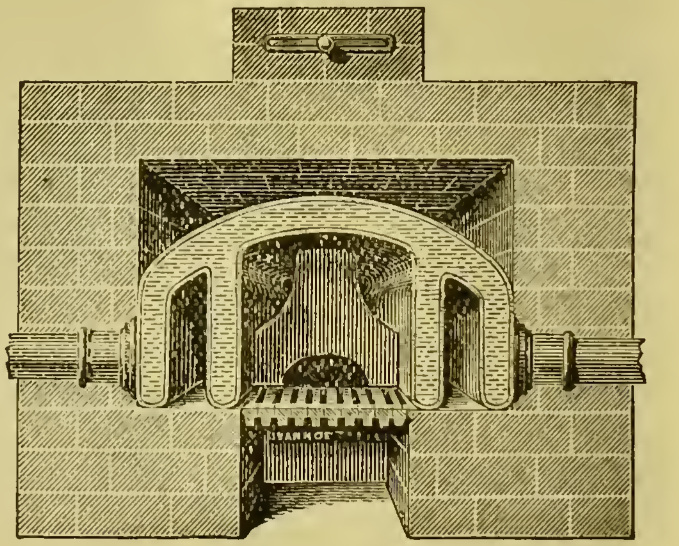

Fig. 166.

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* The "Delta." R. Jenkins & Sons, Rotherham.

considerable importance, as in so many situations a tall shaft is by no means admissible, and an increased natural draught cannot be obtained except by increasing the height of the chimney (see Chimneys).

Fig. 167* shows a boiler that is considerably in favour and of a powerful character, presenting, as it does, all possible direct heating surface to the fire (except what can be gained by cross tubes, &c.), and having almost the whole of its outer surface enveloped in flame when in use.

The shape of this boiler particularly adapts it for withstanding a heavy internal pressure, as is always obtained with an apparatus that may extend up three or four floors of a high building (not in ordinary horticultural works). In such cases it is never advisable to use the simple type of saddle boiler, as it will probably bulge out in the middle, inside, and be ruined, perhaps even before the fire is lighted. The pressure becomes enormous in the boiler of an apparatus that extends to any considerable height, and the cylindrical shape is best able to withstand it. This argument, however, does not apply so much to cast-iron boilers.

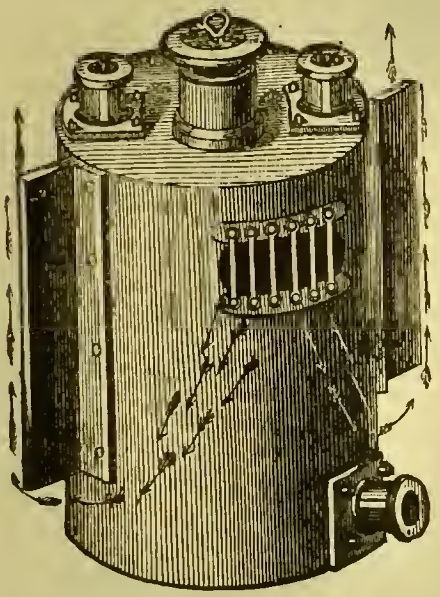

Fig. 167.

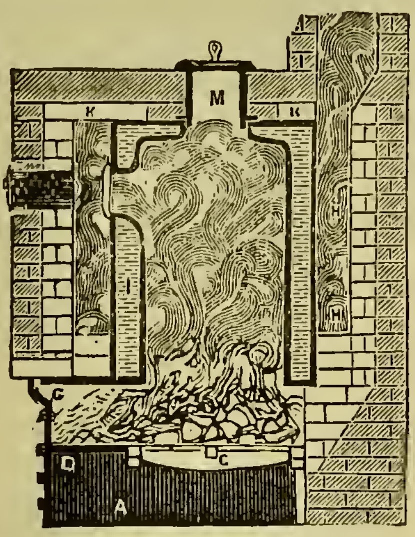

Fig. 168.

Fig. 168 shows the method in which this boiler is fixed. The flames and heat from the interior pass out by way of the grated opening near the top, as shown. The grating is provided to prevent the fuel falling through into the flue, the boiler being specially adapted for filling with a full charge of fuel. The flame is then caused to pass down the sides beneath the mid-feathers, then up again into the chimney at back; the top surface of the boiler is not made use of. This boiler can be had with waterway mid-feathers if desired, and it is made in sizes ranging from 350 to 3700 feet of radiating surface (actual).

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* The "Excelsior." Lumby, Son & Wood, Limited, Halifax (England).

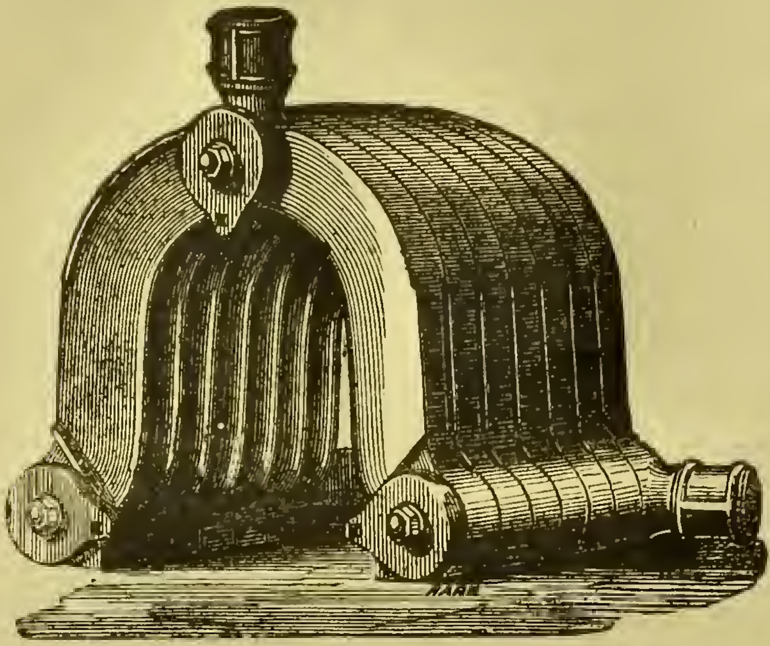
Fig. 169.

Fig. 169 is an ingenious form of cast-iron sectional saddle boiler that has been found very effective. Its fixing is simple, as it does not require flues of the ordinary character. It is

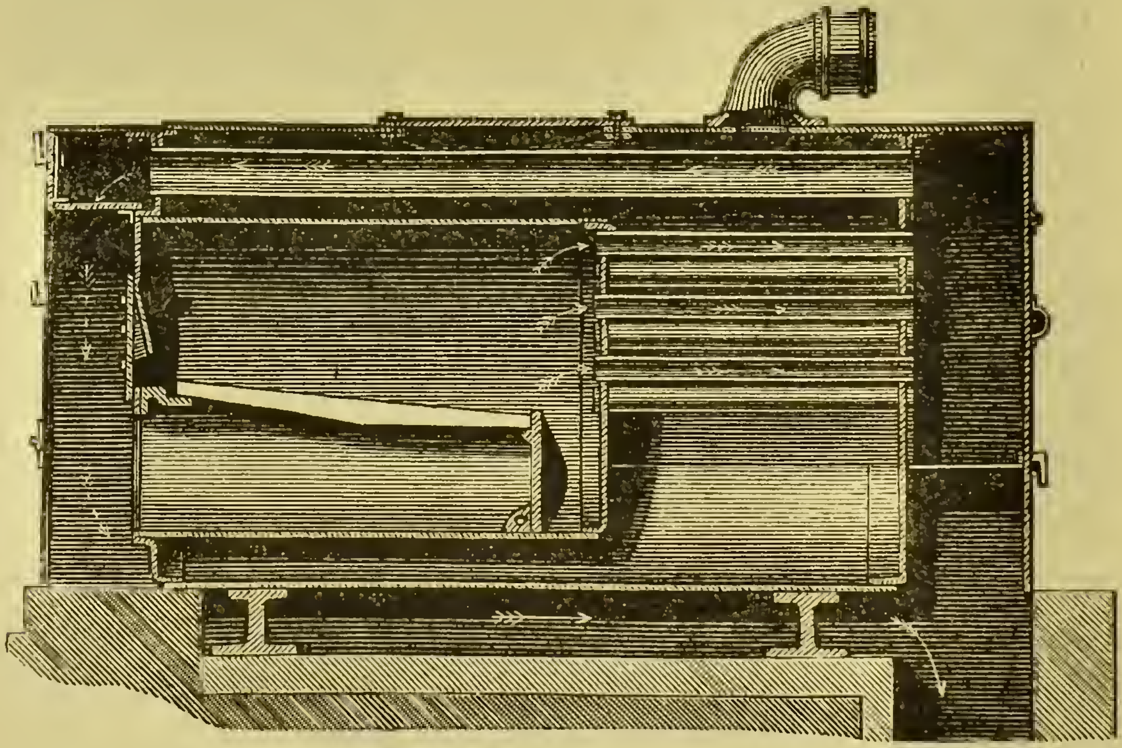
Fig. 170.

built in a chamber of its own form but a little larger, and the flame passes from the interior through the slotted apertures between the sections.

Figs. 170 and 171* illustrate a somewhat unique form of horticultural boiler, it so much resembling the multitubular boilers used for steam generation. It is a most effective type of water heater, as in addition to the cluster of tubes through which the heat and products pass when first leaving the fire-box, there is an upper range or saddle of about 14 tubes which fulfil the part of a return flue. This double arrangement of tubes presents a very large area of effective heating surface, and apart from the rapid results obtained, it effects an economy in space that is valuable in boilers of high power. It will be seen that the tubes do not interfere with that very necessary feature in horticultural works, viz. the ability to bank the fire so that it will go the night without attention. The setting of this boiler is very simple, as shown.

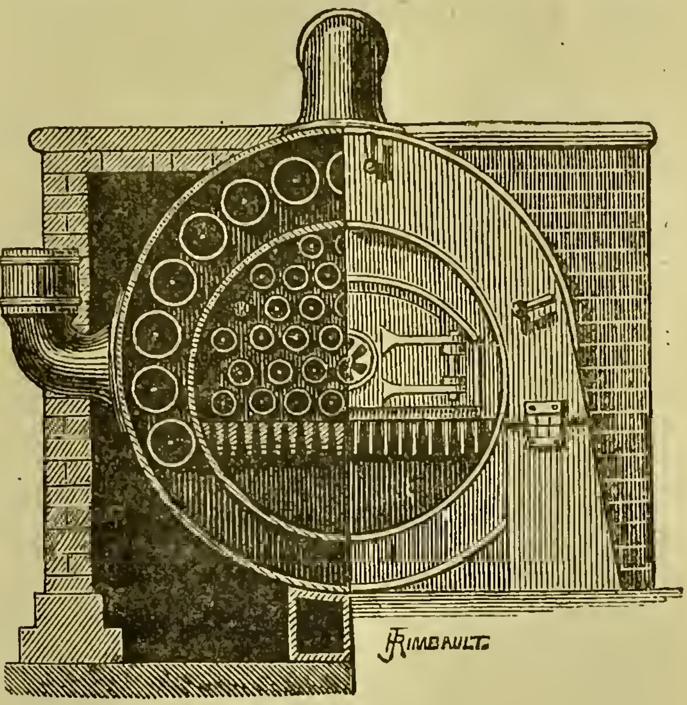

Fig. 171.

Fig. 172 is Deard's coil boiler, but differing from any coil boiler previously referred to, and it is adapted for large works. This coil is of cast iron, built up in sections, but presenting in other ways the same appearance as one of wrought-iron pipe. It will be noticed that the pipes forming the coil

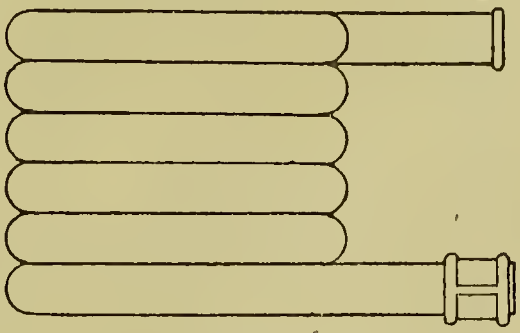

Fig. 172.

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* From the catalogue of John Bellamy, Byng Street, Millwall, London.

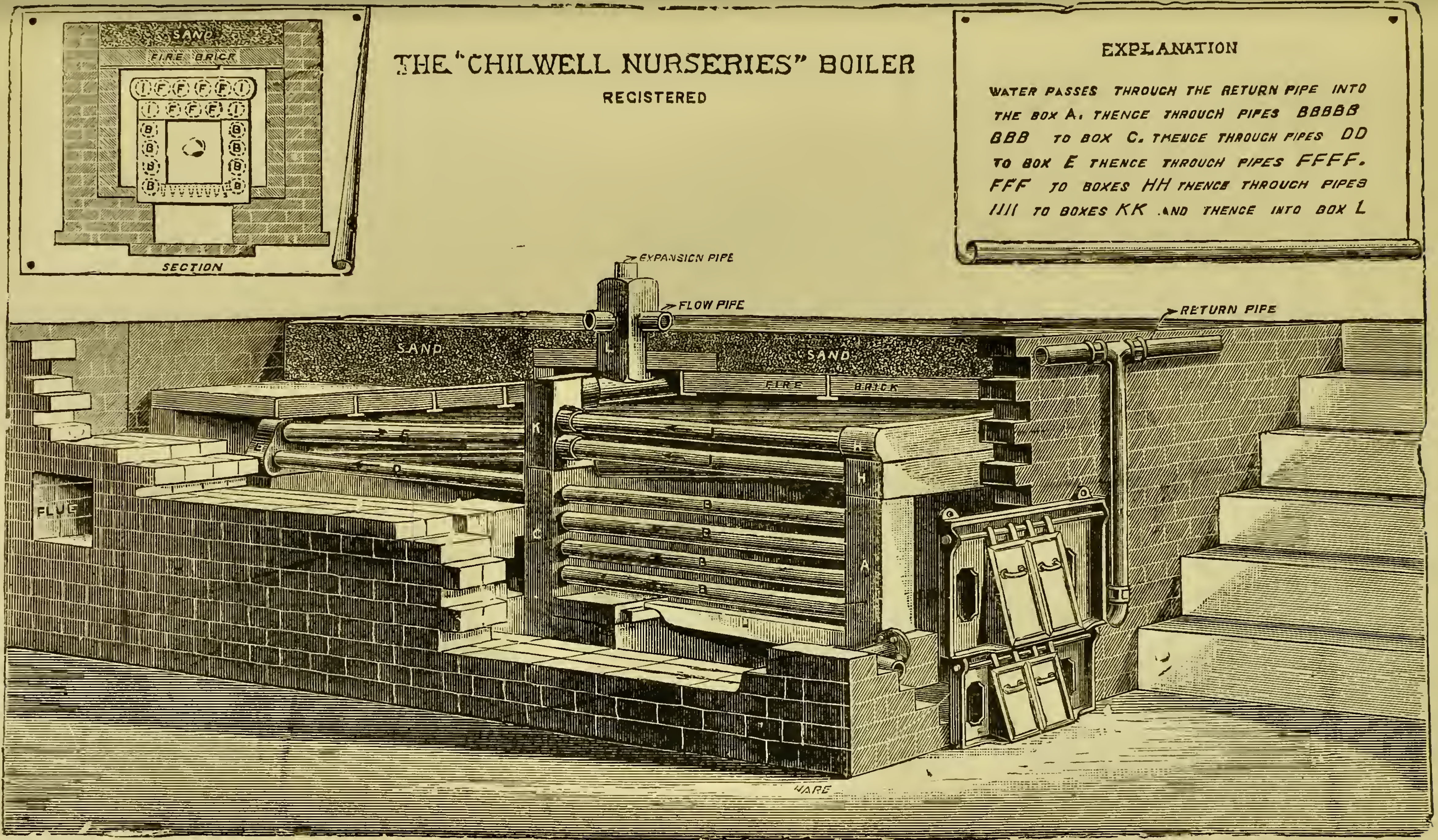
are set down close together without any passage-way or space between them for flame or heat to pass through. This constitutes one of the chief features in the patent of which this boiler is the subject. It is claimed that by preventing egress of flame through the sides of the coil, but conducting outside with flues with three or four vertical mid-feathers, a considerable improvement in results is effected. In this instance it is by preventing the free escape of useful heat into the chimney as takes place with an open coil with a powerful furnace, an effect that is, however, considerably modified with the small independent coil boilers. By closing up the coil a larger surface is obtained in contact with, and near, the fire than with an open coil, and this undoubtedly has gone far to make this boiler more efficient.

The usual method of fixing this boiler is to arrange for the furnace to be within it and to lead the flame out at the top to pass up and down the outer surface by vertical mid-feathers. The heated products escape from the interior by a flue-way at the top of the boiler, and then, by the feathers provided, it is led up and down the boiler, finally escaping by the chimney which leads off at the back. An auxiliary or pilot flue is commonly provided leading direct from the furnace to the chimney, to draw up the fire quickly when lighting, this flue being closed by a damper when the fire is fairly established. In fixing, an arrangement for feeding at the top is necessary; the customary emptying service is needed, and particular care should be given to the easy cleaning out of sedimentary deposit.

The size of the pipe constituting the coil is 3 inches, and it is usually fixed upon and connected with water bars of a shape to permit of the stoking tools passing under the lower edge of the boiler, which could not be done with the ordinary flat bars in this instance.

Fig. 173* is the "Chilwell Nurseries" Boiler (Foster and Pearson's patent). This is a horizontal tubular boiler, consisting, as shown, entirely of tubes, fastened into box ends, the

* The Beeston Foundry Company, Limited, Beeston, Notts.



EXPLANATION

WATER PASSES THROUGH THE RETURN PIPE INTO THE BOX A, THENCE THROUGH PIPES BBBBB BBB TO BOX C, THENCE THROUGH PIPES DD TO BOX E THENCE THROUGH PIPES FFFF. FFF TO BOXES HH THENCE THROUGH PIPES IIII TO BOXES KK AND THENCE INTO BOX L

Fig. 173.

flames and heated gases circulating through and around them. Theoretically, and to a great extent practically, no more effective boiler can be made than one of tubes. Boilers for steam generation and boilers for every other known purpose when required to be highly effective are invariably provided with tubes, either tubular flues or tubes containing water. The advantage is in the fact that a tube is all heating surface. Any other form of heating surface has usually some part idle, but not so with a tube which is effective from end to end.

Notwithstanding this, tubular boilers (consisting entirely of tubes) are not so largely used as would be expected. It is not due to any recognised fault, and no hesitation need be felt in recommending or using them. Doubtless they have suffered at the hands of unskilled fixers, for perhaps this form of boiler more than any other is liable to suffer in this way. It is very necessary that a tubular boiler be set upon a good principle to render it effective. This means that the fixer should be skilled at his work and know (as skilled boiler fixers do) what is the effective action of flame and heated gases, as well as of radiant heat from the glowing fuel.

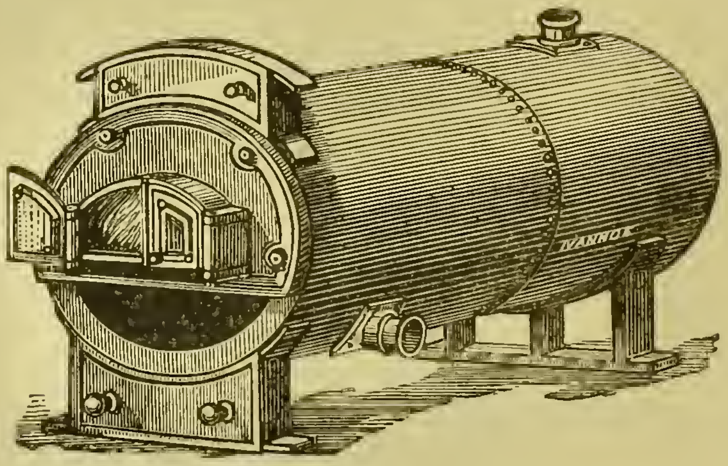


Fig. 174.

In the hands of a good setter every boiler is at an advantage, but a tubular boiler is especially so. Good work with these yields very excellent results. The particular boiler being referred to gives every opportunity for good results to be obtained, as it is made in two sections with the middle bridge provided. In many such boilers the bridges and deflecting feathers have all to be planned out and built by the fixer, which calls for much skill. This is a cast-iron boiler, and the illustration shows the method of fixing.

There remains one more boiler to be noticed, as it has done enormous and long service, and in very many cases is still found advantageous in use, notwithstanding the variety of new patterns designed since its introduction. This is the Trentham or Cornish boiler, Figs. 174 and 175,* elevation and longitudinal section. The large amount of room this necessarily occupies is an objection sometimes, but for many years it was considered very economical in fuel, and this doubtless has prolonged its use. It is doubtful whether, with all its years of useful service, it will continue to have the preference it has enjoyed, though for steady results many engineers still consider it superior to most of the newer patterns.

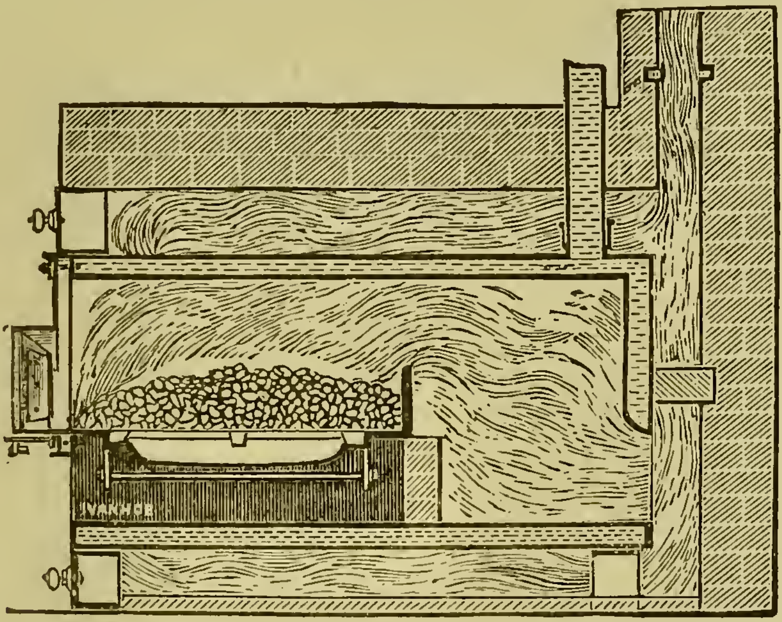


Fig. 175.

This boiler is very commonly fitted with cross tubes behind the fire box ; and immediately behind where the fuel rests there is provided a "bridge," a raised part which causes the flame and heated gases to impinge upon the upper surface inside. The sectional drawing shows the boiler as having a waterway check end, which again adds to the total effectiveness, as already explained. The flame, after it leaves the interior, is conducted by means of flues to and fro the length of the boiler outside, some engineers preferring to first carry the flames under the boiler, and then over the top to the chimney; others first carry the flame over the top of the boiler, and then along the bottom to the chimney, much in the same way as explained with the saddle boiler. Each has an argument in favour of their respective ways, but in actual results there is not the least doubt, for the reasons several times mentioned, that the former method is best. There are sweeping doors for the flue-ways at top and bottom of the fire front, as shown in both cuts.

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* Manufactured by R. Jenkins & Co., of Rotherham.

This is another boiler that should have two or more flow pipes leading away from it; it is of too large a character to have all its water pass away up one pipe, unless it was of unusual size.

CHAPTER XIV.

UPON WARMING BUILDINGS FOR RESIDENTIAL OR BUSINESS PURPOSES.

Low-Pressure Systems.

What constitutes the difference between these works and those erected for horticultural purposes — Warming private residences by hot water, and the prejudice that has existed—How unreasonable this prejudice is—The many great advantages of this method of warming—The pressure exerted in pipes which extend far vertically—Unsuitable boilers—High motive power to circulation—Main pipes and general details.

THE preceding pages deal almost exclusively with hot-water works adapted for warming horticultural buildings, work that is of such a different character to that about to be described as to make it almost a distinct business. There are many different phenomena, as well as constructional details, peculiar to each, and under no circumstances can the two works be described or treated together. The active principle of each is identical, and it is in no way necessary to repeat the information given as to the theory and practical demonstration of convective action, nor the general particulars as to the natural laws that govern the efficient working of a hot-water system. This has all been given in Chapters I. and II., and will be found to apply to every kind of hot-water apparatus alike.

It is the conditions that effect such a difference in the two forms of apparatus; one wholly on the ground, the other being (in many cases) almost wholly vertical work. In the former, pipes, and large pipes, constitute the whole apparatus; in the latter there are pipes, but they are of a different kind and size, and only fulfil the office of conduits to convey the water to the points where heat is required. The heat distribution is effected from different isolated points, and not by heating surfaces extending all round the area to be warmed. There are also other characteristics peculiar to this work, but these can be treated as the description proceeds.

There has been a distinct prejudice against hot water as a heating medium in residences, and although this is lessening to a marked degree there is certainly a complete absence of enthusiasm in its favour, as yet, which should not be. The prejudice, which is openly expressed by many when this mode of heating is suggested for residence works, is not founded on experience but on a mistaken idea of the results. It is seldom that any one having an apparatus properly erected does other than speak highly, if not extravagantly, of it, for as a source of comfort this mode of heating excels all others. It is commonly supposed that the source of warmth is perceivable as with other modes of heating. Also that the heat diffused has some peculiar and disagreeable character of its own, having no relationship to the heat diffused from an open fire. That it is not so healthy as the latter is a prevailing idea, and other opinions more or less condemnatory.

All this is so very wrong and arises from ideas founded on imagination, or on experience of some overheated, ill ventilated, possibly dirty, lecture hall full of people whose persons and clothing are accountable for exhalations of many kinds. It is not uncommon for educated people to blame this state of things to the hot-water pipes, either partially or wholly, but only because their experience of hot-water heating has been confined to such places. To state the reverse of this, a house properly warmed by hot water has the atmosphere perpetually of a still summer evening. This is no exaggeration whatever, as the air is of the most comfortable temperature the body requires ; it seems quite still, owing to the complete absence of obvious draughts ; and there is no reason why the source of heat should be more perceivable than with the summer evening typified. As to odours or anything perceivable to the nose or respiratory organs, there will be nothing different to what the same house might have if heated by any other means. The heat from hot water has no impure nature, in fact heat from every source is devoid of this. It is as pure and healthful as light. There are modes of heating that render the air dry, but this does not apply to hot-water works in residences. The writer has seen houses heated by hot water in which the occupiers have subsequently removed all doors and substituted curtains. This may not meet every one's taste, but it goes to show that it is possible, in winter, to live in the whole house and not be confined to a tightly closed room, as is too often the rule.

Perhaps the greatest benefit of this method of heating is the total absence of disagreeable, and no less hurtful, draughts of cold air. The prejudiced almost make capital of this by pointing out what risks must be run by those leaving a house warmed at every part and going into the cold outer air of a winter's day. These risks are totally imaginary, as can be testified by every one having experience. On the other hand, the interior of a house heated by grates is a greater source of danger and illness. There are draughts in all rooms, corridors, and entrance halls. The latter in a large house are as cold as the outer air, and passing across from one heated room to another accounts for more chills than going outdoors properly clothed to resist the cold. There is no reason why such places should be lower in temperature than reception rooms, neither should the latter be a real source of danger to any one sitting near a partially open door. This can all be obviated successfully without in the least degree impairing ventilation. Entrance halls, staircases, landings, bed, bath, and dressing rooms, all more or less uncomfortable in cold weather, can be made just as agreeable as they are in summer; not the hottest summer time, but the heat the occupant likes best. It is only a valve handle that has to be turned to give any temperature required, ranging all the way from summer to winter.

The Englishman's love of an open fire and its cheerful blaze is a literal truth with an incorrect meaning, for who seeks or enjoys the cheerfulness of a fire with the thermometer registering 65° to 70°? A fire is at an advantage in infusing a sense of comfort to anyone coming out of the cold air, but after the actual warmth is obtained the sight of the fire conveys no exceptionally agreeable feeling. This can be noticed when a fire has overheated a room; the feeling towards it, and its appearance, is then more of aversion.

The advantages claimed for hot water are by no means over-rated, but there is another, or we might say others, in economy in fuel, labour, and maintenance. In residences, a vertical boiler to take a charge of fuel sufficient for several hours can be tended by a maid-servant. This is one fire to replenish and clean instead of several; and its replenishment is at much longer intervals than any single grate fire. The fuel consumed for the warming of the whole building will not exceed that otherwise used in three rooms. In business houses the general economy is very marked, added to which there is the complete immunity from fire and dangerous features. Except for the boiler itself, all other parts of the apparatus can be disposed as anyone pleases without transgressing the Building Acts or local bye-laws; and without being considered an extra risk on a fire insurance policy.

In hot-water works for buildings, where the apparatus extends upwards, perhaps, several floors, there is introduced a feature which is not present in horticultural works which rarely extend more than a few feet above the boiler. This feature is the strain that is exerted upon the lower parts of the apparatus by the pressure or weight of water.

In case there are readers unacquainted with elementary hydraulics, it must be explained that this has no reference whatever to the bulk of water alone, although the pressure of water in pipes is exactly proportionate to its weight. The contents of a pipe two feet four inches high,* and having an internal area of one square inch (the nearest sized pipe we have to this is $1\frac{1}{4}$ inch diameter) will, when full, contain 1 lb. of water, and a boiler having a pipe this length connected with it vertically, and filled with water, would be said to have a pressure of 1 lb. to the square inch within it. This pressure is, as stated, merely the weight of 1 lb. of water pressing on the water in the boiler.

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* This may be termed practical measurement; it is not strictly correct, as the actual figures are ·4328 of a pound to the foot.

The common impression would be that this pressure of 1 lb. would be distributed over the whole of the boiler (which is correct), but diminished by being spread over a large surface. This, however, is not the case, as the pressure of 1 lb. will be exerted upon every square inch inside the boiler, top, bottom and sides, so that the aggregate pressure brought to bear upon a moderate sized boiler by the contents of this short length of pipe may be two tons.* This needs consideration in various ways in the works now alluded to, as we do not have merely the effect of this short length of pipe to deal with, but with an effect twenty times as great when the apparatus extends up three or four floors.

This pressure is exerted precisely the same with any sized pipe that may be used, whether it be ½-inch or 4-inch, but it is only vertical pipe that counts—that is, the vertical height between the supply or feed cistern and the boiler. This height will give the pressure exerted in a boiler by calculating 1 lb. for every 2 feet 4 inches between the points named. From the boiler upwards the pressure diminishes in exactly equal ratio, every 2 feet 4 inches in height, the pressure per square inch in the pipe, or in any appliance connected with the pipe, being reduced 1 lb.

In case it may not be clear to all the readers why the pressure is precisely the same with any sized pipe, it may be explained that the standard of pressure is a supposed mass of water 2 feet 4 inches high and 1 inch square, this mass or body weighing exactly 1 lb. Now, if we could stand this upright, we should have one end of it standing upon a space exactly 1 inch square, and this small space would be pressed upon by a weight of 1 lb. If we took another body of water exactly the same size and placed it close up against the other they would together be a quantity representing the contents of a pipe with an internal area of 2 square inches, and we get double the weight or pressure, but the pressure is upon 2 square inches of space at the bottom ; we have not increased the pressure per square inch. We have doubled the pressure certainly, but taken double the space to exert it upon, or, in other words, a pipe of a size equal to 2 square inches exerts double the pressure of a pipe of 1 square inch, but as it exerts it upon double the area there is no increase of pressure per square inch. On the other hand, a pipe of an area of half a square inch would only contain sufficient water to exert a pressure of half a pound for every 2 feet 4 inches of its height, but this half pound would be exerted upon every half square inch in the boiler, and so with the reduced pipe there would be no reduction of pressure per square inch in the boiler.

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* Any treatise upon hydraulics or hydrostatics explains this. Without this peculiar phenomenon the hydraulic lift, hydraulic press, &c., would be of no use.

The same reasoning permits us to have a various number of pipes entering the boiler without in any way varying the pressure, as the pressure of water, both in the pipes and boiler, exerts itself exactly in all directions. No one pipe would cause more pressure than another, and no part of the boiler would escape more than another. It will also be understood that it matters not what quantity of water is contained within the feed-cistern, the fact of the cistern having a large capacity makes no difference if the height of the cistern remains the same. Of course, if we had a tall cistern full to the top, there would be a greater pressure exerted than with a shallow cistern, supposing both were upon the same floor. The height of the water line in the cistern adds to the pressure in the boiler exactly as if it were a pipe, viz. one pound to the square inch for every 2 feet 4 inches vertically.

This strain upon a boiler has no injurious effect to speak of, but it firstly necessitates the use of a proper shaped boiler when a high pressure has to be borne (say, for three or more floors of a warehouse). The ordinary saddle boiler, for instance, of $\frac{3}{8}$-inch plate, may become bulged on the inner side, even when first charged and cold; and it does not permit of the boiler being used so long as with a low pressure, for so soon as the boiler gets a little weak from wear and tear, the heavy pressure will bring about its destruction. With low-pressure works the boiler might wear until it was quite thin, and still do good service.

If the boiler was small there would be no particular fear of bulging, but with a plain saddle boiler, four or five feet long, it would be most probable, and consequently, when a strong pressure has to be borne a strong form of boiler is used. Preference is commonly given to a cylindrical shape, as a cylinder is capable of bearing enormous strains if equally distributed inside, as it would be with water (or steam). To those, however, who wish to avoid responsibility in this respect, it may be suggested that the vertical pressure be mentioned to the boiler maker, when purchasing, and he will then supply what he can safely be responsible for.

In the bursting of a circulating apparatus containing water only (an exceedingly rare occurrence) there is no danger whatever to be feared, unless it occurred through the expansion pipe, and all such outlets being tightly closed (by frost), as in this case probably steam might be generated, which would be an element of great danger. If a burst occurred through the mere pressure or weight of water, there would instantly be a violent outrush of the liquid, but this would only be harmful to those who might be near enough to be scalded, supposing the water was hot; further than this nothing need be feared. It is such a different matter with steam, for the elasticity of this fluid has a rending effect of a truly terrific nature, and a burst is a highly dangerous occurrence. Water may be considered (for all practical purposes) incompressible, and consequently inelastic, as it can only be compressed one-sixteenth of its volume under a pressure of 20,000 lbs. to the square inch.

There is an erroneous idea, somewhat prevalent amongst workmen, that the pressure, in an apparatus that extends some distance vertically, aids the circulation. Perhaps this error is fallen into easily from the fact that, as a rule, the greater the pressure, the more rapid the circulation, for an increase of pressure indicates increase in height, and, as a general result, we may always look for a quicker circulation the higher we go (see p. 34). But it must be clearly understood this is in no way accounted for by the pressure, which is exerted equally in all parts, and if it increased the flow of water down the "return" pipe, it would just as greatly retard the flow of water up the "flow" pipe, for it presses with practically equal force down each. The erroneous idea, however, is fairly common, and workmen will be found sometimes putting the supply cistern much higher than necessary with the view to increase the circulation; a very unnecessary thing in these works.

The circulation, that is, the strength of the motive power and speed at which the water circulates, is, in these works, if properly constructed, everything that could be desired, as reference to p. 34 will make clear, and is sufficient to overcome many obstacles that would render a horticultural apparatus inefficient by reason of the exceedingly low motive force in these latter works.

There is invariably a high speed of circulation in all vertical apparatus, but the motive power does not increase in exact ratio with the increased height of the pipes, and we might reasonably expect that there could be a height which would not permit of the circulation taking place at all, but this limit is never reached in building works of an ordinary character, even with the highest blocks of warehouses or residential flats that exist at present, neither is it likely to be reached just yet. In America buildings of enormous height are common, but whether any are heated by water the writer cannot say. The majority are heated by steam, in which case the pressure due to water would be absent. It is, however, a fact that American boilers and radiators are sent out tested to withstand very high pressures, higher than most of those of English make. With a building of, perhaps, twenty floors, the strain in the lower parts of the apparatus requires careful consideration, to say the least. It would be better to have two distinct sets of apparatus, if possible, the boiler for the lower floors being in the basement, and that for the upper floors, somewhere halfway up the building.

There is another result introduced in vertical works that sometimes needs consideration, which is, that with a rapid circulation in the main pipes there is a likelihood of the water passing by the branch services without freely circulating through them as it should do. This frequently needs particular attention, but methods for overcoming this difficulty can be better explained when showing some example works.

The main pipes of these works are, as a rule, small compared to those in greenhouse work, for, with the high velocity of the circulation, frictional resistance plays a less important part. Tables giving the sizes of mains (both horizontal and vertical), sub-mains, branches and radiator connections will be found in their proper places, and can be followed when the apparatus distributes its heat wholly by radiators. Radiators are now made to contain a quantity of water having a fixed relation to the area of radiating surface, and this quantity is small compared to what the older forms of coils and hot-water pipes hold. Owing to this difference the tables cannot be held to apply if plain pipes or pipe coils are used instead of radiators. The pipes should never be smaller than the sizes given, but a size larger may be used without hesitation if desired.

The question of covering pipes that are used merely for conveyance of water, and not for radiation, was spoken of in horticultural works, and will also be found referred to under appliances and fittings. Practically, all the pipes in these works are distributing services merely, and not used for heat radiation. Heat is radiated from them, however, just as freely as from other parts of the apparatus (unless it is prevented), and this means a real loss of fuel and labour with decidedly lessened efficacy. All mains and distributing services should be covered to prevent loss of heat, otherwise, in a large apparatus, the pipes equal possibly ten good radiators in heat dissipation. The boiler has to make good this loss somehow, or the heat where required will be decreased proportionately.

Air vents are of course equally necessary in these as in other works, but it is not the usual thing for air pipes to be admissible unless the works all occupy a low level. Air pipes are decidedly the best whenever they can be used, but if an apparatus extended up several floors of a building, the vent pipes, from the lower part, would have to be of a most expensive and inconvenient length, quite unreasonable, in fact, and introducing one or two objections. Air pipes are also considered unsightly, even for warehouse work, especially with made up coils or radiators, which would necessarily have the air pipe connections rather prominently in view. As a rule, some form of air cock is used,* and these, as explained, require regular attention to allow the air to be expelled, for it collects at all the high points very rapidly. When an apparatus is wholly devoid of air pipes, it is usual to provide an expansion or steam pipe at the top of the circulation, in event of the apparatus overheating ; but not all make this provision, as no danger need be feared while the cold supply pipe is clear. Any unusual expansive force would relieve itself through this, but causing most probably a sudden overflow of water. It is best to have an expansion pipe—it is practically always possible, and it should be of fair size. It might as well be of the same size pipe as the mains, considering it only wants carrying up a short distance to be above the supply cistern. It will be seen presently that the circulation can be made to pass through a tank at top, this tank being filled but a little way up, and having either a loose cover or a good-sized expansion pipe from it ; this plan is very satisfactory. The tank only needs to be of moderate size.

The water supply to these erections is provided for by a cistern of proper proportions, see p. 52, but it is not so usual for these to be filled by hand as with horticultural works. Consequently a ball valve has to be introduced, and unsatisfactory as these things are in general use, they are still more unsatisfactory for this purpose. They have so little work to do, that they need frequently looking to, even the best of them, as the ball arm gets stuck and hung up, and does not admit the water to replace that evaporated. This, however, is not a serious matter, as with a moderately high apparatus there need be no fear of the pipes and boiler getting entirely exhausted of water for at least a very considerable time, and there would be various symptoms to indicate the fault. There, however, remains the fact that there is no ball valve that can be thoroughly relied upon for this work, and they must be inspected periodically.

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* See Appliances and Fittings.

Where the pipes (main or branch) pass along conspicuous places, they may be decorated in colours to match their surroundings, either oil or water colours (but it is better to cover them to prevent loss of heat, as explained). In the same way the radiating surfaces, whether pipes, coils, or radiators, can be painted any colour, and many of them permit of very skilled treatment in decoration. Bronzing or gilding or any bright metallic surface is objectionable as decreasing the radiant heat projected (see p. 11).

The boilers have been fully treated (Chaps. XII. and XIII.). It only needs to be mentioned that in ordering these the sizes of pipe connections should be mentioned, and also state that it is wrought pipe, otherwise the plain sockets for large cast pipe may be fitted and sent, causing a deal of trouble.

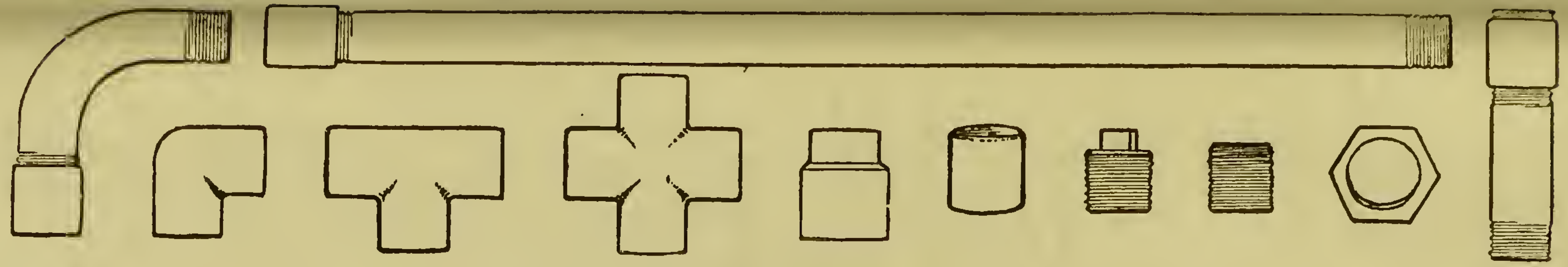
CHAPTER XV.

PIPES, FITTINGS AND SUNDRY APPLIANCES FOR BUILDING WORKS.

Pipes and fittings—Qualities—Price list—Malleable iron fittings—Soft cast fittings—Specially convenient forms of these and their uses—Eccentric reducing socket—Stop valves and cocks—Angle radiator valves—Union elbows—Air cocks—Thermometers—Altitude Gauge—Safety valves.

THE pipes and fittings, used for main and branch services in these works, are almost invariably of wrought iron, the same in fact as are used in hot-water works for domestic supply, and also in steam heating, the only difference being in size, and this difference is very small. This pipe has screwed joints of an ordinary character, a joint eminently suited for the pressure that has occasionally to be withstood. There are two qualities of this tube, the cheapest being that used for gas services, and is of a natural black colour. The best, or steam quality, is of a much stronger make, and is sent out from the works painted a dull red. Both these qualities can be had galvanised if desired, but they are then, of course, both of the same colour, and can only be distinguished by the thickness of metal. The steam quality should always be used (unless the works be of a very temporary nature), as the difference in cost is not so very great, and although the black tube is used in some instances it is a bad practice, and leads to complaints. No engineer with a reputation to uphold thinks of using gas tube even with the smallest and cheapest works.

The universal list of wrought tube and fittings on the following page applies to all qualities alike, whether black,

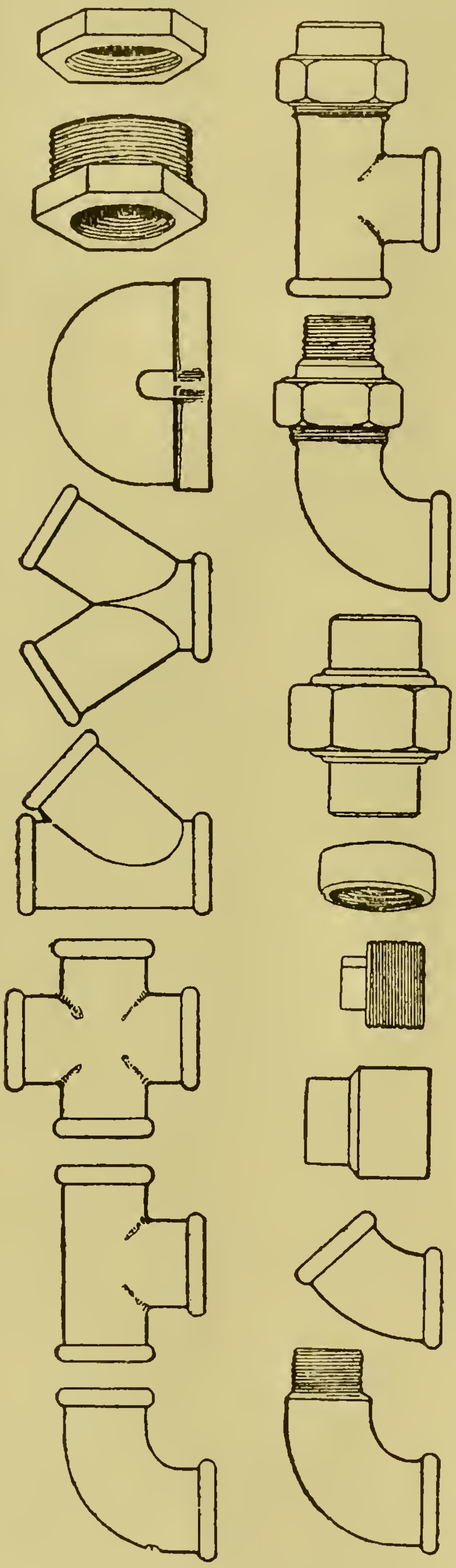


PRICE LIST OF WROUGHT-IRON TUBES AND FITTINGS.
(This list is subject to a rather large trade discount.)

Internal Diameter.	½ in.		¾ in.		1 in.		1¼ in.		1½ in.		2 in.		2¼ in.		2½ in.		3 in.		
	s.	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*	
1. Wrought-iron welded tube, 2 to 14 feet	0	4¼	0	6	0	8½	0	11	1	2	1	9	2	7	3	3	4	6	per ft.
Short piece, 3 to 11 in.	0	6	0	8	0	11	1	1	1	4	2	3	4	0	4	9	7	0	each.
" 12 to 24 in.	0	9	1	0	1	4	1	8	2	0	3	0	4	6	6	3	9	0	"
2. Connector, 3 to 11 in.	0	8	0	10	1	0	1	3	2	0	3	0	4	6	5	6	7	6	"
" 12 to 24 in.	0	11	1	2	1	6	2	0	2	6	4	0	5	6	7	0	10	0	"
3. Bend	0	8	0	11	1	3	1	9	2	3	4	3	6	6	10	0	16	0	"
4. Tee, equal or diminishing	0	9	1	0	1	3	1	9	2	6	3	9	6	0	9	6	16	6	"
5. Elbow (square)	0	8	0	10	1	2	1	9	2	3	3	6	5	6	8	6	14	0	"
6. " (round)	0	9	1	0	1	4	1	11	2	6	3	10	6	6	10	0	16	0	"
7. Cross	1	5	1	9	2	3	3	0	3	6	5	3	10	6	16	0	30	0	"
8. Nipple	0	3	0	3½	0	4	0	6	0	8	1	0	1	9	2	3	3	6	"
9. Back nut	0	3	0	3½	0	4	0	6	0	8	1	0	1	9	2	3	3	6	"
10. Cap	0	4	0	5	0	6	0	8	0	10	1	3	2	0	2	6	4	9	"
11. Plug	0	4	0	5	0	6	0	8	0	10	1	3	2	0	2	6	4	9	"
12. Plain socket	0	3	0	3½	0	4	0	6	0	7	1	0	1	6	2	6	3	6	"
13. Diminished socket	0	5	0	6	0	7	0	9	0	11	1	3	2	0	3	0	5	0	"
14. Flange	1	0	1	2	1	4	1	6	1	9	2	6	3	9	5	0	8	6	"

For relative area of pipes, see Appendix.

red, or galvanised. The difference in price is effected by allowing more or less discount according to the quality.



In America * wrought pipe is used the same as here, but they have discarded wrought fittings for much the same reason that they discarded wrought boilers. The forms of wrought fittings did not reach their standard of perfection, as fittings of cast iron can. With cast iron it is possible to make fittings upon lines quite impossible with wrought iron. Their elbows, for instance, have a sweep that makes the use of bends unnecessary. Then there are branch pieces of the utmost value in horizontal connections, but apparently impossible in wrought iron, as they have not been made as yet. The fittings referred to are cast, but some are malleable, others of soft cast iron. The smaller sizes used are of the

* The writer has had occasion to refer to the practices in America more than once, but it is only because their experience of these works is so much greater than our own. In that country a radiator corresponds to a fire-grate in England, consequently the demand and the practice of hot-water works is very great compared with ours. It is this that accounts for their greater experience and perfection in detail.

former, while the larger sizes are of the latter, though both sizes can be had of either.

These illustrations* depict a number of the fittings in common use, and every hot-water engineer will appreciate some of the special forms shown. The branches fulfil a particularly useful purpose in making horizontal connections,† in conjunction with the 45 degree elbows, as will be seen by Fig. 176, as compared with Fig. 177. The latter shows how a horizontal branch appears made with a wrought-iron tee. With vertical mains the horizontal branches require a deal of consideration to ensure the heated water entering and circulating through them (as will be seen later). Nothing is more conducive to bad results than the abrupt branch shown in the last illustration, and for want of convenient branch fittings several more or less troublesome devices have to be resorted to.

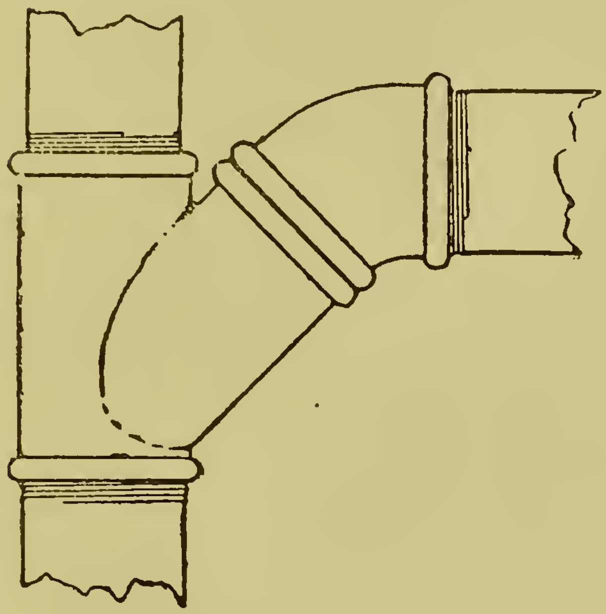


Fig. 176.

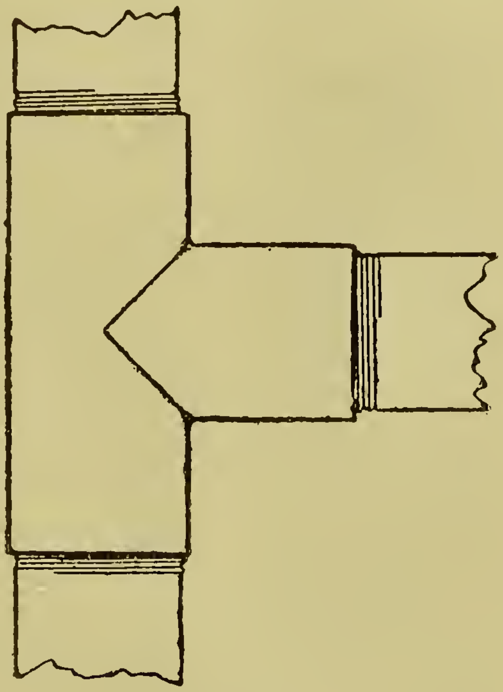


Fig. 177.

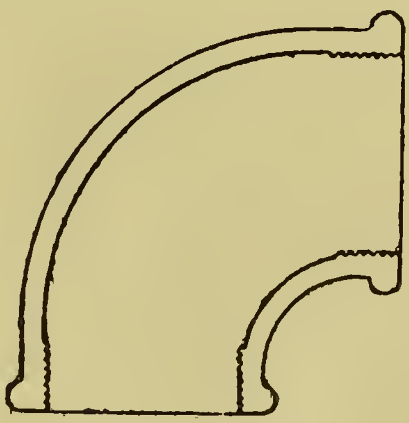


Fig. 178.

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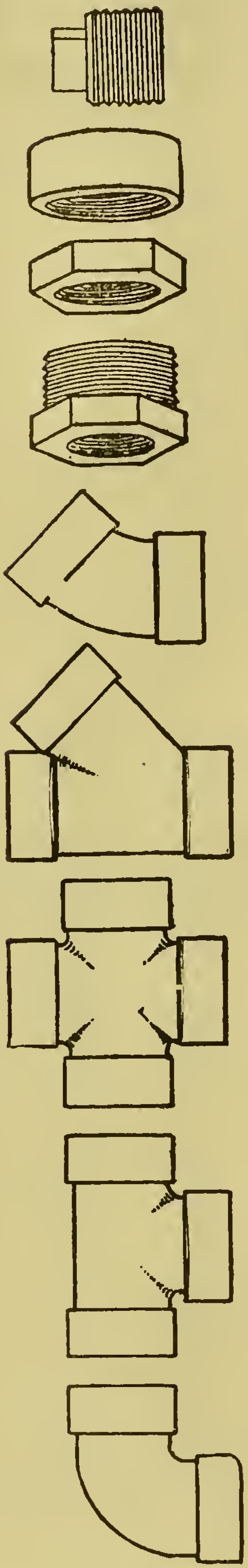
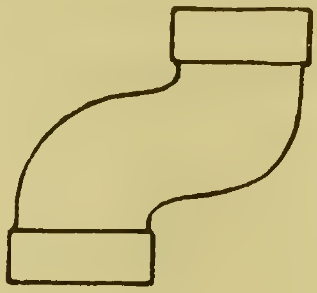
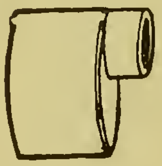
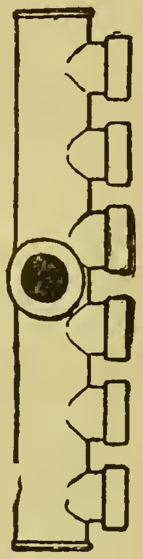
* The illustrations of pipe fittings are from the author's catalogue.

† They are also useful in pump work.









Next to the Y branch will be seen a syphon-end, a fitting largely used and appreciated in horticultural works, but not made in England in small sizes for wrought pipe as this is. Next to this is another novel fitting, a bushing, which under certain conditions fulfils a more useful purpose than a reducing socket. There is also an elbow made with male and female ends, as will be seen, and the union and union-elbows and tees are all in malleable iron at low prices. The prices of all cast fittings, whether malleable or soft iron, are well below those of wrought fittings.

In point of finish there are two ways in which they excel wrought iron, in addition to their better form. One is that the thread stands clear of the substances of the casting, as Fig. 178, which is the section of an elbow. Wrought fittings have the threads cut in their substances, and in many cases when a pipe is screwed in as far as possible a thread-to-thread joint is not effected, because the pipe cannot get beyond where the thread ends in the fitting. Added to this the threads of these fittings are all tapped slightly taper, which greatly aids in making a sound thread-to-thread joint. It is not usual to use hemp and packing material with these to the extent we do with wrought fittings. A little jointing composition is all that is needed.

In the next set of fittings illustrated are examples of those made of heavy soft cast iron. The metal is tough, not brittle, and the strength of the fittings is such that any pressure can be put upon them, up to that which would rupture the pipe itself. There are the same convenient shapes as with the malleable iron, and the tapping and general finish is the same. In price they are still less.

With this set of fittings there are two which deserve special mention. The first is an eccentric reducing socket, a reducing socket with the small aperture thrown out of the centre, and shown at the upper edge of the fitting. The utility of this is very great when reducing the size of horizontal mains. It will be seen in the examples given in the later pages, that mains are (in all two-pipe systems) reduced in size as the work is passed. That is to say, the mains commence a full size for the whole of the work, then when a fair-sized branch is passed the mains can be reduced a size, and reduced again when more work is passed.

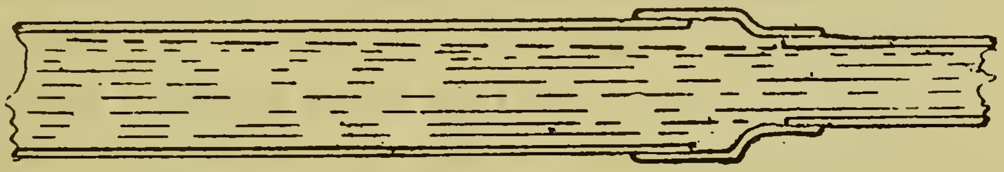


Fig. 179.

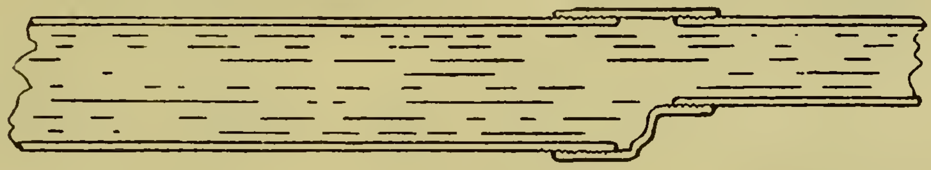


Fig. 180.

In reducing horizontal mains with the ordinary reducing fittings, there is every risk of locking air in the large pipe, as will be understood from Fig. 179. This illustration represents a horizontal flow pipe of say 3 in. reduced to 2 in., rising from left to right, the reduction being by an ordinary wrought reducing socket. It will be seen how an air pocket is made in the upper part of the large pipe. Of course, if a vertical branch came just at the reduction, and on the large pipe, this would release the air, but in any case an eccentric reducing piece is more workmanlike. Fig. 180 shows a similar reduction to the last, but made with an eccentric fitting.

The other fitting to be noticed is the offset, a double elbow, or swan-neck, as it may be termed. These are made to set off various distances, the same as the similar larger fitting that is made for and largely used in horticultural works. With vertical pipes which have to set back at nearly every floor in a high building, due to the walls being of less thickness as they get higher, this fitting is very useful, though the English plan is to set (bend) the pipes at these points.

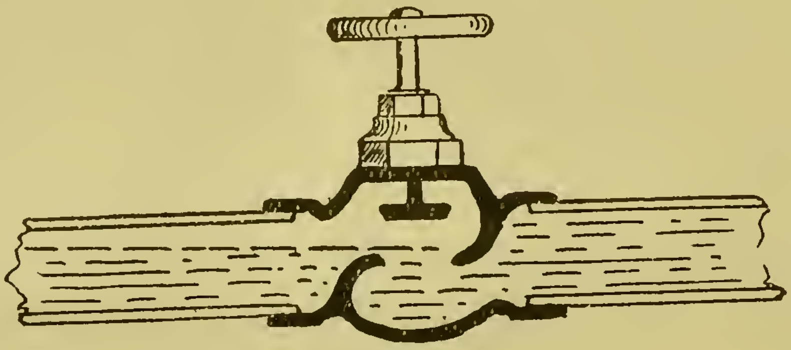


Fig. 181.

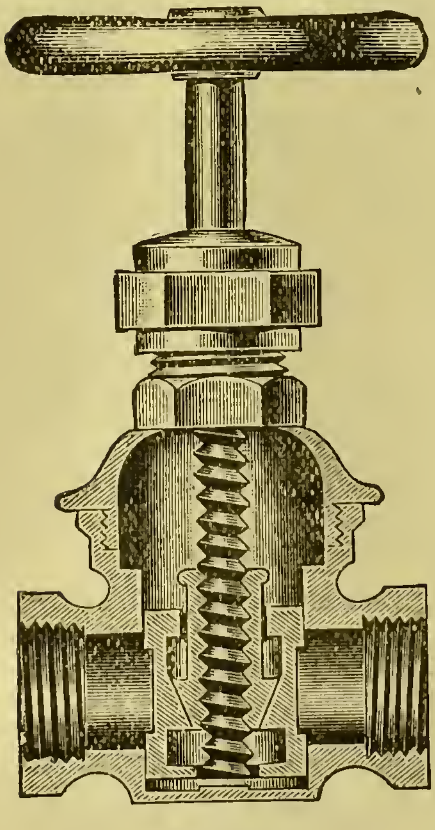


Fig. 182.

Of valves for these works there are practically two kinds. One is a valve in which there is a spindle with disc which comes down on a seating. This is a screw-down valve and in section it is much as Fig. 181. This illustration shows the failing of this valve in locking air in its upper part so that the water can scarcely pass, and its sectional shape is also bad for the free clear circulation that is always desirable, if not absolutely wanted. The valve, however, loses its ill features to a large extent if *fixed on its side*, but of course many would object to its appearance fixed thus, unless in horizontal mains near a ceiling.

For horizontal work it is better to have the Peets, or gate, pattern, as Fig. 182. This is a clear, straight-way valve, which, when full open, has a straight bore through it, equalling the size of the pipe and in a direct line with it. This is also a screw-down valve, and the best pattern that can be used for the purpose named.

For radiator valves this latter gate design is best if an angle valve cannot be used, but wherever possible the angle pattern should be used, as Figs. 183 and 184. The latter has a union attached, the former has not, but in other respects they are the same. These angle valves have an interior construction the same as that just condemned (Fig. 181), but the ill-features explained do not exist when the valve is angle shaped. In recommending this shape for radiator connections it is that such a workmanlike and rather handsome effect is produced with no pipe or pipe fittings visible. To obtain this result in perfection, a gun-metal union elbow, as Fig. 185, should be used at the opposite end of the radiator. The connections are made to the main beneath the floor, as

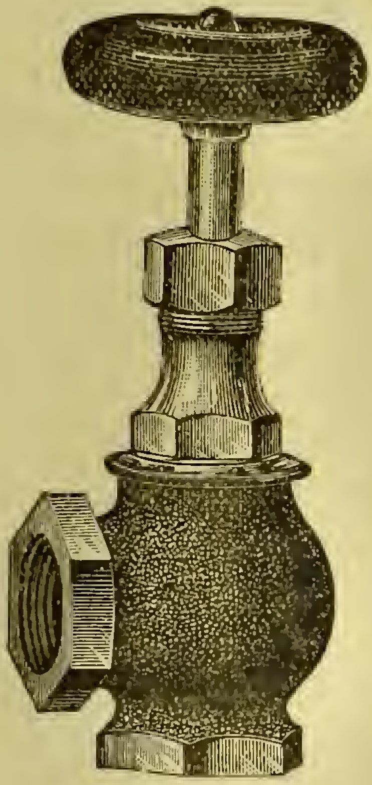


Fig. 183.

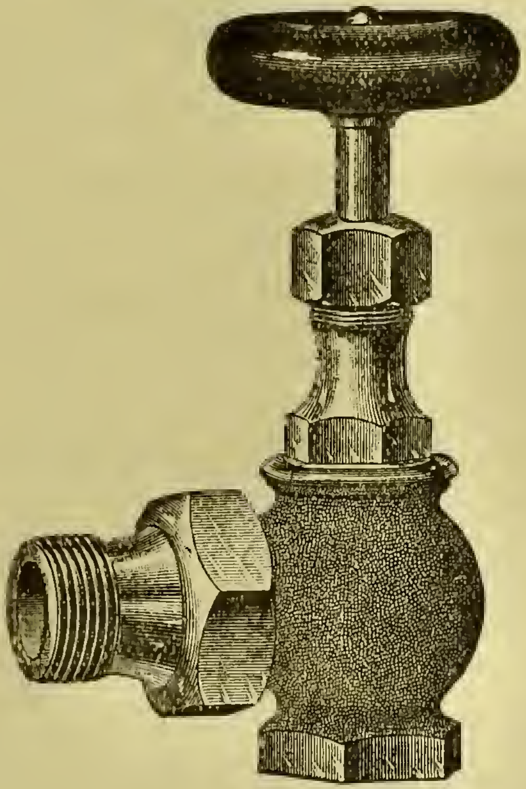


Fig. 184.

Fig. 186, and no better appearance could be desired. Union cocks and union elbows are recommended as making better connections than cocks and elbows without unions, and by having these two fittings nickel plated with a well decorated radiator, the appearance will bear every criticism.

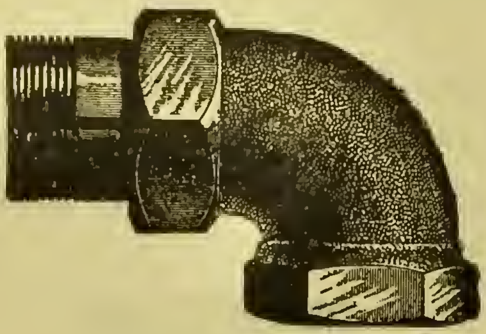


Fig. 185.

Another ingenious valve of American origin is shown in Fig. 187. This shows the construction, except that the plug portion in the middle is not seen to have a clear aperture at bottom, which it has for the water to rise up through. The plug is not perfectly tight fitting, and really does not need to be, for it is seldom that a radiator requires to be shut dead off or to be made quite cold, except in the warm weather when of course the fire is let out. The loose fitting plug allows a feeble circulation to occur at all times, even when the valve is quite closed off, and this effect is aided in some of the valves by a pinhole made in the shell of the

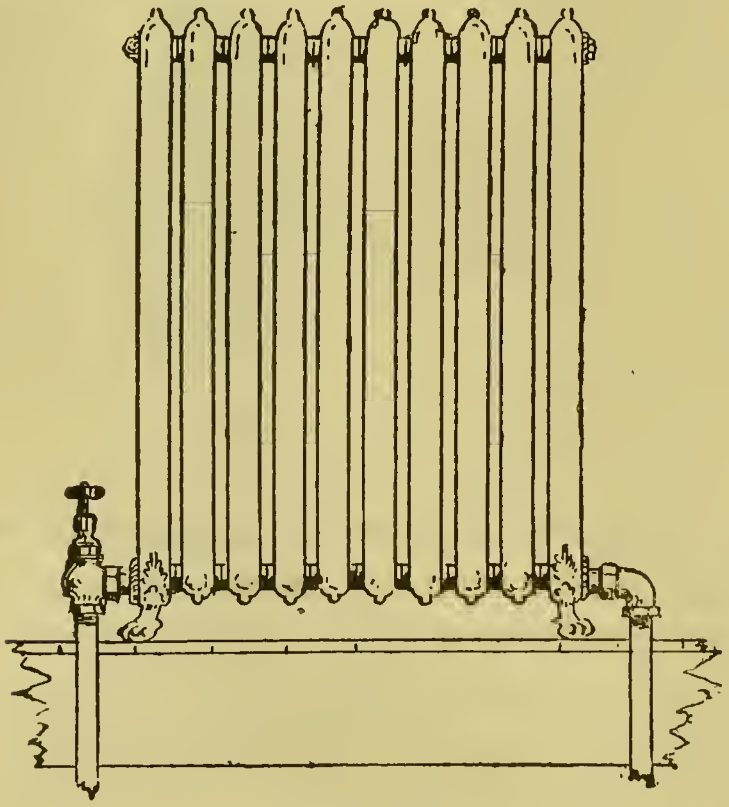


Fig. 186.

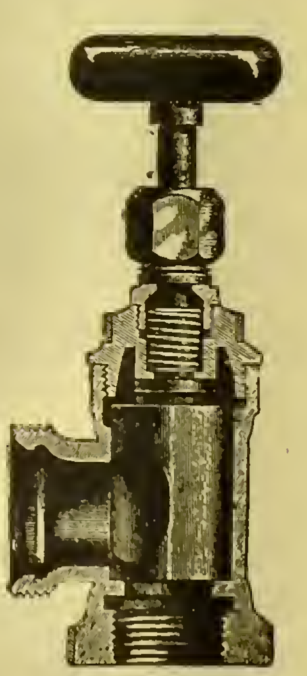


Fig. 187.

plug itself. The object of this is to prevent the radiator getting so cold that the water in it might freeze in event of its being shut off and forgotten in very cold weather.

Figs. 188, 189 and 190 represent typical examples of air cocks, all of which can be had nickel plated. The first one is probably the neatest form made, and can be had with a small ebonised wood wheel if preferred. The second is similar, except it is provided with a loose key. This is often considered desirable in residence works where there are children, in schools, also in business places where some of the public idle about. The third is a cock of different external appearance to the others, but its working parts are practically the same. This can be had with loose key.

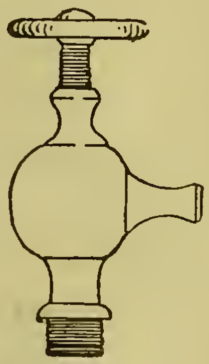


Fig. 188.

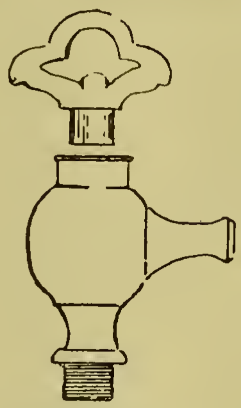


Fig. 189.

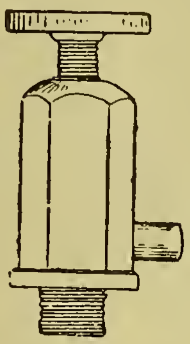


Fig. 190.

There are now two or three different kinds of automatic air vents, or Aspirators, to be had, but the writer's experience of these does not justify their full recommendation yet. They are ingenious and good, but not perfect in every instance. By the time this book requires further revision they may be nearer the absolute perfection that should be experienced of them, in which case they will receive the notice they certainly deserve. It is a fitting that fulfils a pronounced want, particularly when the apparatus is large.

In England there are, to the best of the writer's belief, no automatic devices for controlling the heat of an apparatus, and the adoption of any means of indicating the temperature is comparatively rare. Thermometers may be hung in rooms or offices, and of course indicate the temperature of the air, but an appliance that should appear on every apparatus, large or small, is a thermometer to indicate the temperature of the water in the pipes. Fig. 191 shows a thermometer of this kind, and it may be fixed at any point in the flow pipe where it can be easily inspected. If necessary, a small branch flow could be taken through a manager's or engineer's office, and a glance will then show whether the water is at a suitable heat for the day.

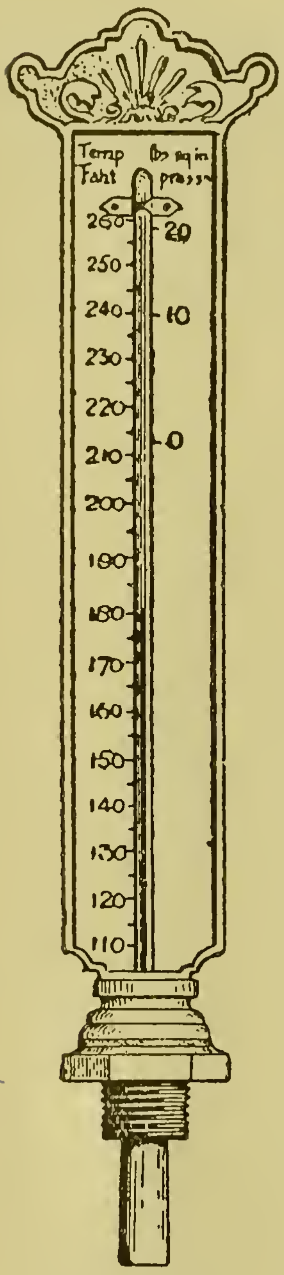


Fig. 191.

The air temperature, the weather in fact, changes almost daily, and sometimes more frequently, and in busy premises the internal temperature increases late in the day. In the ordinary way some one decides that the boiler damper may be drawn out or pushed in a little, but this is a very uncertain way of getting fairly exact results. A thermometer of this kind (Fig. 191) indicates plainly how the fire is controlled and tended, and an electric bell communicating with the attendant should keep the temperature very even. These thermometers are very ingeniously constructed, so that in event of the mercury bulb or tube being broken no water escapes, and a new tube can be put in without any water escaping, and without emptying the apparatus or interfering with its regular working.

Fig. 192 illustrates an altitude gauge which indicates the height of water in the apparatus and any irregularity in pressure. The figures on the dial indicate pressure of water in vertical height, so that when an apparatus is fully charged the double-ended pointer at once shows the number of feet the normal water level is above the boiler. The dark hand or pointer is coloured red and is placed under the indicating pointer out of sight while the pressure is normal. Should there be any excessive pressure from any cause whatever the upper pointer will move and expose the red one, which thus answers as a danger signal. Should the pressure fall, by shortness of water, the upper pointer descends, exposing the red one again, which means that something is wrong. If the gauge stood as illustrated it would indicate shortness of water. The coloured pointer stands at the normal height pressure of 34 feet (the cold supply cistern being 34 feet above the gauge, which does not necessarily have to be on the boiler); the water pressure indicates 25 feet, showing that either the ball valve is stuck shut or the water supply has failed in some way, and attention is needed.

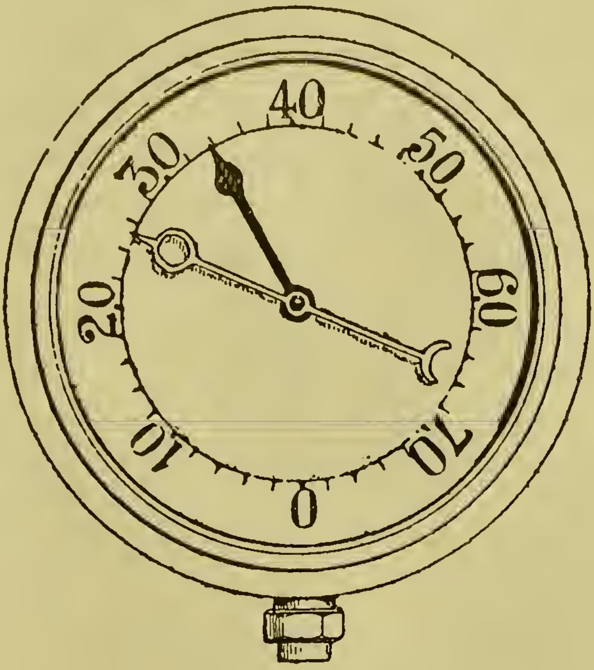


Fig. 192.

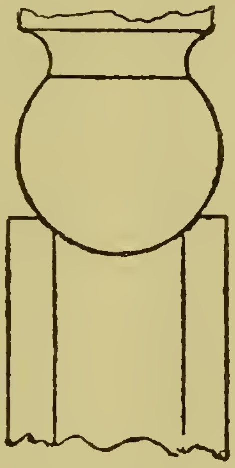


Fig. 193.

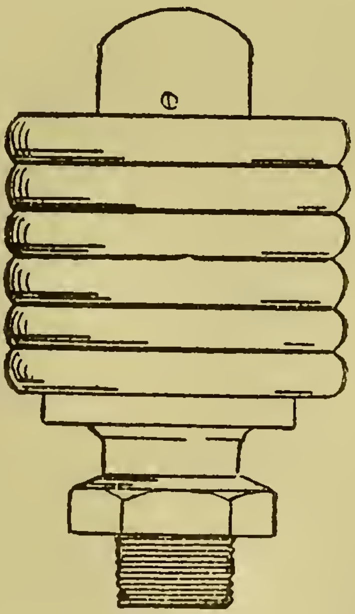


Fig. 194.

Every boiler or heater should be provided with a safety valve, and this should be of a reliable kind. A spring valve is not recommended, and if the more reliable kinds, deadweight or lever, are used they should have a very narrow seating. The seating should be as near knife-edge as possible, which is generally effected by bringing a nearly square edge against a rounded surface. In section this appears as Fig. 193, the lower part being a tube with a true right-angled upper edge, into which a ball surface fits, as shown. The object of this narrow seating surface is to prevent the two parts growing tight together by oxidation. With the safety valves of steam boilers this care is not so necessary, as the valve has fairly constant use which keeps it in order. With hot-water boilers the valves quite rarely come into use, and unless purposely tested, the working parts may not be disturbed for years. Fig. 194 represents the regular appearance of a dead-weight valve, and the sizes vary from ¾ inch to 1¼ inch. The latter for rather large boilers.

CHAPTER XVI.

COILS AND RADIATORS.

Pipe coils with box ends, and methods of jointing—Expansion joints—Methods of connecting coils — Distinction between a coil and a radiator — Radiators and details concerning them — Methods of jointing radiator sections—The right-and-left screw nipple—The push nipple — Sizes of radiator connections — Examples of English and American radiators, ordinary and ventilating.

THE heat-radiating surfaces in buildings now very seldom consist of plain pipes like those used in horticultural works. It is a comparatively short time ago that these pipes were used chiefly, and were sufficient in themselves to prevent this mode of heating becoming popular. Pipe coils, that is, stacks of pipes with box ends, such as appear in the beginning of this chapter, are still used, and the demand must be very fair judging by their appearing in so many iron-founders' catalogues, together with the ornamental cases used to cover them. In warehouse work, drying rooms, trench work, in churches, and such purposes, the ordinary pipes can still be used, but even in these places radiators are at an advantage in effectiveness, economy of space, and not gathering dirt and dust on the heating surfaces.

Should pipes or pipe coils be used in these works the joints must have careful consideration if the water supply is high above them. The joints of hot-water pipes in greenhouses have no pressure to withstand, and are made accordingly, but in instances where a good pressure exists care must be exercised. Some of the patented joints described on p. 151 are made to withstand heavy pressure. The rust joint will also stand, so will the red and white lead joint if it is allowed sufficient time to well harden before the apparatus is charged.

The distinction between a coil and a radiator is at present in a very undefined state. A stack of plain pipes fixed horizontally is always called a coil, even though it may not be of a coiled form, but have box ends as Fig. 195, whereas if the pipes are of a slightly ornamental character and fixed vertically, as some of those illustrated further on, it is termed a radiator. Both act precisely the same, are connected in the same manner, but with the radiators there is a greater area of radiating surface to the amount of water held, and quicker results are obtained. The vertical arrangement of pipes has the particular advantage of keeping them free from dust.

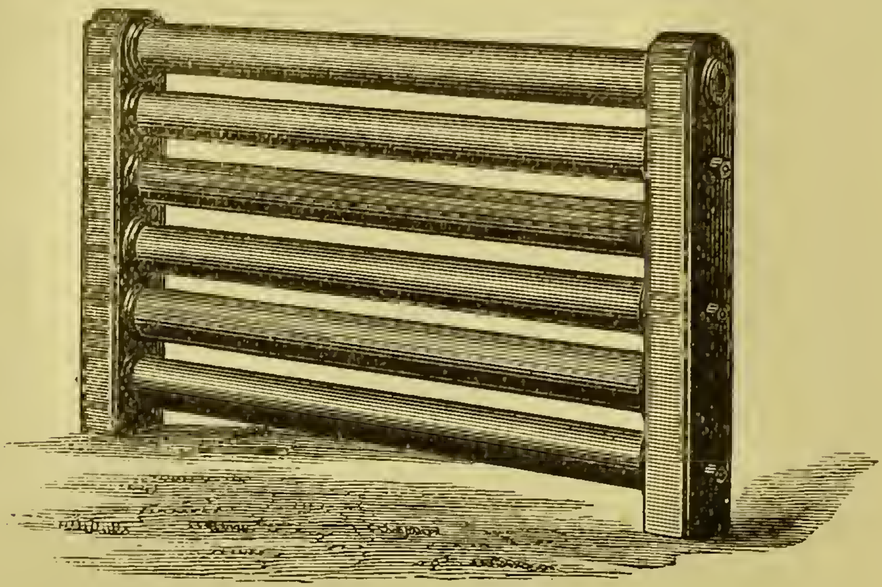


Fig. 195.

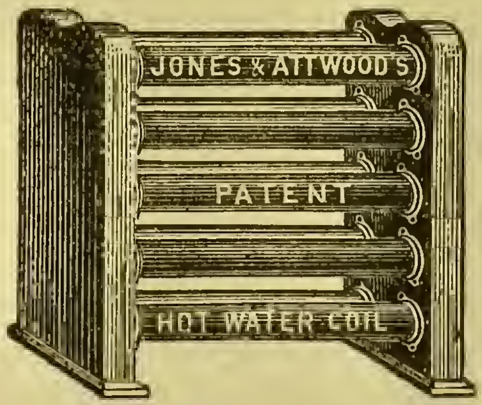


Fig. 196.

The common form of box coil is composed of plain pipes inserted into socketed holes in the boxes, the joints between the two parts being made with iron borings, as described at p. 141. The illustration, Fig. 195,* resembles a common coil in appearance, although this example is one fitted with expansion joints which permit of more rapid and simple erection. Fig. 196* shows another coil with expansion joints and having a double row of pipes. There have been several forms of pipes introduced, having gills or plates cast on their exterior surface. These gills are of solid metal, having no waterway within their substance, but simply go to extend the area of radiating surface. Their use is referred to on p. 8, where a typical pipe is illustrated. The gills in that example run longitudinally, and when so arranged are suited for pipes which have to be fixed vertically. Pipes of this kind, but made up and used as radiators, appear in Fig. 213, &c. With pipes fixed horizontally the gills appear as flat rings around the pipe at right angles to its length. An example of this pipe made up into a coil appears in Figs. 197 and 198,† the former illustration being a plan of the latter. This principle is also adapted in a very ingenious way to circular upright (pedestal) coils, one pattern consisting of a series of ring or annular pipes with gills, and another being sections of a fair-sized pipe, each section having gills or feathers round its circumference. Every description of gilled pipe must be fixed so that the gill plates do not lie flat to collect dust, for radiating surfaces must be clean to be effective.

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* Made by The General Iron Foundry Company, Upper Thames Street, London.

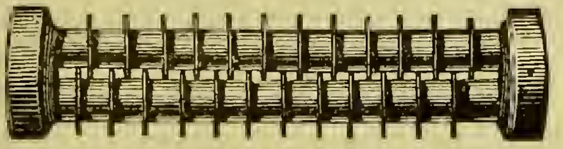
Fig. 197.

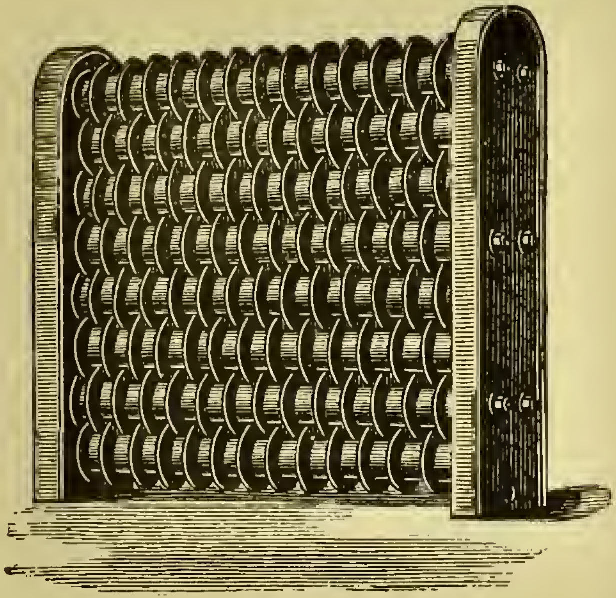
Fig. 198.

The usual objection to what are called coils is their unsightliness. They may be suited for warehouse work, workshops and such like, but few people adopt them in exposed positions for halls, rooms, or public places without a casing, and this latter arrangement has several drawbacks. In the first place, a coil case, even of a very open pattern, obstructs and retards the passage of radiant heat, not seriously, perhaps, when once it is all hot and in full working order, but at first starting, or at any time when heating up, it delays results considerably. Another failing is that when a case exists around a coil the total results are much lessened, the cause being that coils (horizontal pipes) collect dust rapidly, and when encased they are not kept clean. The accumulated dust is a great barrier to the free distribution of heat, being composed almost wholly of materials that are poor conductors of heat. Fine shreds of cotton, wool and fibre are all barriers to heat diffusion, so also are the gritty particles which are largely composed of silica, which is another good material for preventing loss of heat. A coil cased and one uncased always give different results from this cause, as the latter would, as a matter of course, be dusted regularly, which attention the former does not have, especially as most coil cases have their parts screwed up, and a workman would be needed to take it down.

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* Jones & Attwood, Stourbridge.

† The General Iron Foundry Co., Ltd., Upper Thames Street, London.

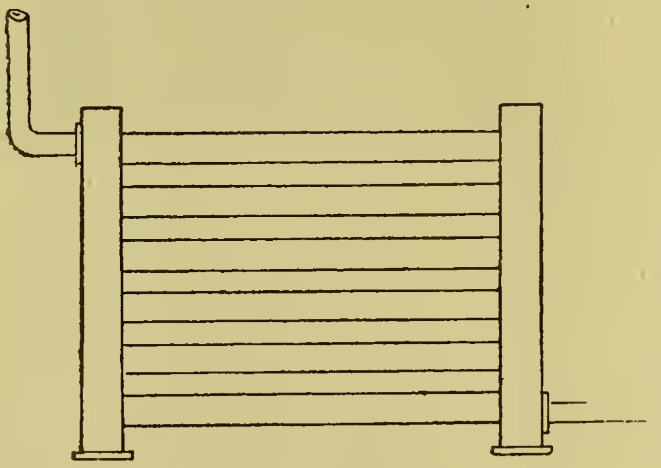

Fig. 199.

Amongst workpeople there exists a considerable difference in opinion as to where the pipes should be connected into a coil, some being very desirous of putting one of the pipes in at the top, or near the top, and the other out at a lower point, as Fig. 199. This would give very good results, but it is quite unnecessary, for both pipes can be carried in and out at the bottom with the best possible effect, as will be seen further on; but when it is convenient to carry one pipe in at the top it can be done so. If a branch flow and return is carried to the coil it can be connected as Fig. 200, or if connected from a main flow and return beneath, then as Fig. 201.

Coils and coil pipes can be had in several designs, ornamental and plain. Gothic and ecclesiastical patterns are obtainable for church work.

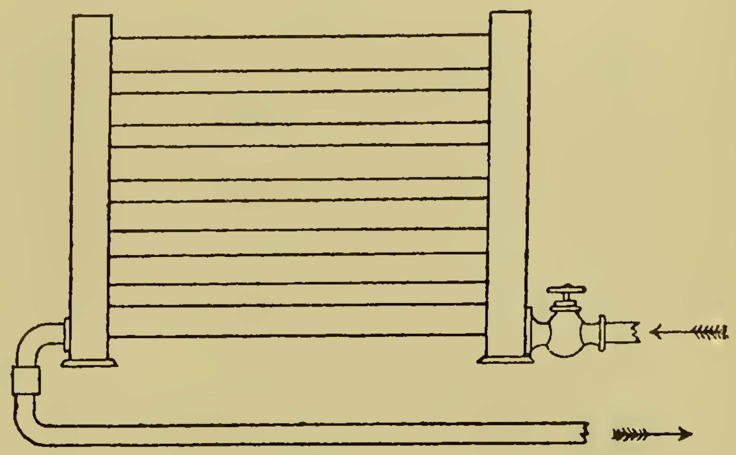

Fig. 200.

In calculating radiating surface of coils, the aggregate length of pipe can be easily measured, and the box ends can be calculated as two lengths of pipe.

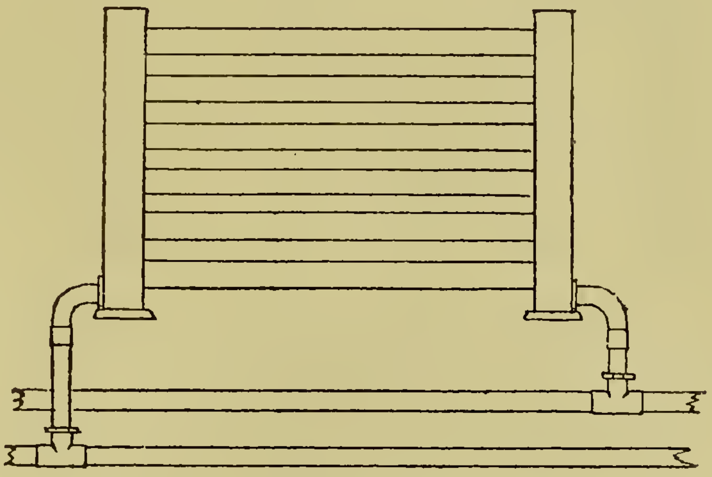

Fig. 201.

RADIATORS.

The modern radiator has undoubtedly done more to make hot-water heating popular in England than any other improvement that has transpired for many years past. It was explained in Chapter XIV. what a very agreeable, natural and healthful warmth can be experienced from a properly constructed apparatus, but even greater advantages than these would fail to overcome the objectionable appearance made by hot-water pipes, coils, or even some of the earlier radiators. This, of course, is in regard to residence work, where appearances are studied, though why the same interest should not be displayed in all public places is difficult to understand. With many of the radiators about to be illustrated, an excellent effect can be obtained by careful decoration, sufficient to remove all prejudice in quite the majority of cases. In the decoration, however, at the hands of a painter, very varied results can be had. So many radiators are painted or enamelled by the hot-water fitter, and if this man's taste runs to one colour more than another, it is to maroon. As a rule the effect with this colour is simply hideous, and now we have decidedly good radiators, the decoration, in ignorant hands, seems likely to be as great a barrier as the design of the castings was.

Radiators must be decorated to match or harmonise with their surroundings, with due regard to disguising the fact that they are iron structures. The writer has a radiator of no more than a neat design, but decorated in two shades of pale mauve, and the effect is described, by those who see it, as exceedingly good. Two shades of mauve is quite a daring colour scheme for such an appliance, but the decorator who did the work showed how capable he was in colour treatment. The Dysart radiator, Fig. 221, is a design that will bear very fine treatment if carefully done. Enamelled pure white, however, it has led inexperienced people to believe it was porcelain; the design of the ironwork favours this idea very much.

The materials that may be used to cover radiating surfaces have already been spoken of (p. 12), but it is desirable to again mention that it is the outer surface or skin of the radiator that affects the radiating qualities. A plain, smooth iron casting is a good heat diffuser; a rusty one is better, but neither are as good as one coated with lampblack, or dull white lead. Fortunately, the ordinary paints, enamel paints and varnishes of commerce, are all more or less good to use, but in these there might be greater care shown. There are some enamels better suited for the purpose than others.

Polished metals are distinctly bad radiators, but with the view to make hot-water heating still more popular, the writer has made an extended series of experiments with polished brass, with the view to making highly finished ornamental radiators of this material. The best of iron radiators are objected to sometimes, but a well-designed brass radiator should be admitted anywhere. The result of the experiments was to find that brass, which is an excellent conductor of heat, could be also made a heat diffuser equal to iron by means of the lacquer used to coat it. Polished brass, unlacquered, had not nearly the effectiveness of iron, and after trying upwards of twenty different lacquers and thicknesses of lacquer, with varying results, it was found that a lacquered bright brass radiator was not only a possibility, but a success.

A deal of care is now being devoted to the iron radiator to make it thoroughly effective. This is done by the proper construction and area of the waterway through it; the quantity of water held in the waterways compared with the radiating surface; and, lastly, the proper disposal of the surfaces so as to allow of the freest heat dispersal. The quantity of water contained by a radiator for the best results is now fixed at about fifteen to eighteen gallons to one hundred feet of prime surface. By prime surface is meant radiating surface which has water on the other side of it, and does not consist of solid metal gills, plates, feathers, or projections of this kind. By a fixed capacity between radiating surface and contents, we are also able to feel confident of what the boiler will do in a given time, with given fuel and attention. In the disposal of the surfaces and parts of a radiator, care is also needed that there be free room for air to circulate through, also for an equally free dispersal of the heat. Heat that is confined, or retarded in its diffusion, represents a loss in efficacy, if not in fuel.

In the jointing of radiator sections there are differences of opinion in England. The different ways of jointing the castings together are by rubber-collar; faced joints with composition or packing; the "push-nipple"; and the right-and-left screw nipple. The push-nipple is a short piece of thin tube turned slightly taper at each end. These ends enter holes in the castings which are bored out to an exact size to fit the nipple closely, and when all the nipples are in position the parts are pressed together very soundly. The right-and-left screw nipple is much used in America, this answering much to the description of the push-nipple, but the ends are tapped one with the right-hand thread, the other left-hand ; the holes in the castings are tapped to correspond. As each nipple is put in position it is screwed up by a tool which goes inside it, and engages against some studs which are made there for the purpose. The screwing up brings the two castings together very firmly and sound, and the joint is found to bear any heavy pressure, and last well.

For radiators which have comparatively small waterways, as just described, there is a recognised size for the connections which feed them with heated water. These sizes are the minimum that can be used for good results, but need not be exceeded unless the radiator is of a kind that has a greater capacity for water. In the latter case one size larger connection can be used if the size of the radiator is anywhere near the limit for the size given in the table.

TABLE. SIZES OF RADIATOR CONNECTIONS.

Connections include the connecting pipes from the main, the stop valve, and the holes drilled and tapped in the radiator.

Surface of Radiator.	Size of Connection.
Up to 16 feet	¾ inch.
16 feet to 48 feet	1 ,,
48 feet to 100 feet	1¼ ,,
100 feet to 150 feet	1½ ,,

Fig. 202 * illustrates a radiator that has a fairly large demand, and which is made in several heights, as required. Its length can be anything by the number of loop castings used, and in the 38-inch height, each casting (a pair of loops) is calculated at four feet prime radiating surface. They are also made up in pedestal form, either square, round, or half-round to stand flat against a wall.

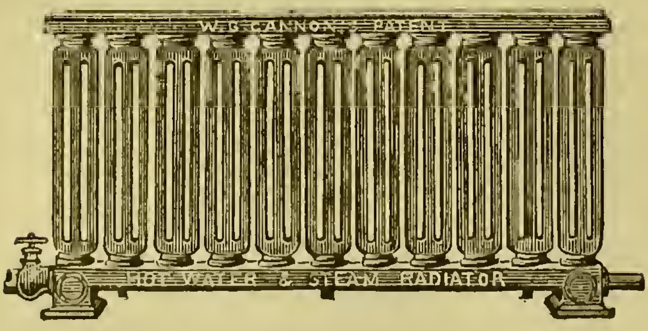

Fig. 202.

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* Cannon's patent. W. G. Cannon & Sons, London Road, Southwark, London, S.E.

Fig. 203 illustrates another by the same maker, this pattern being arranged for ventilating (air inlet) purposes. Air is brought in through the heated surfaces to effectually warm it, as will be referred to under warming buildings by heated air. This radiator is of improved design, its construction admitting of any of the loop castings being taken off without disturbing the other parts, should one leak or become injured from any accidental cause.

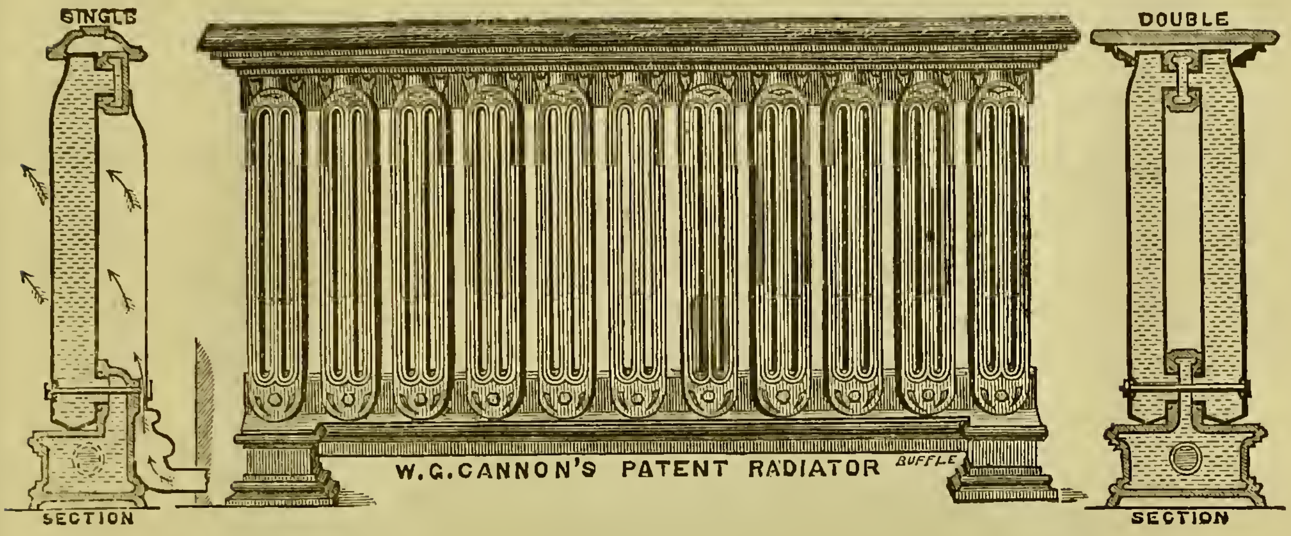

Fig. 203.

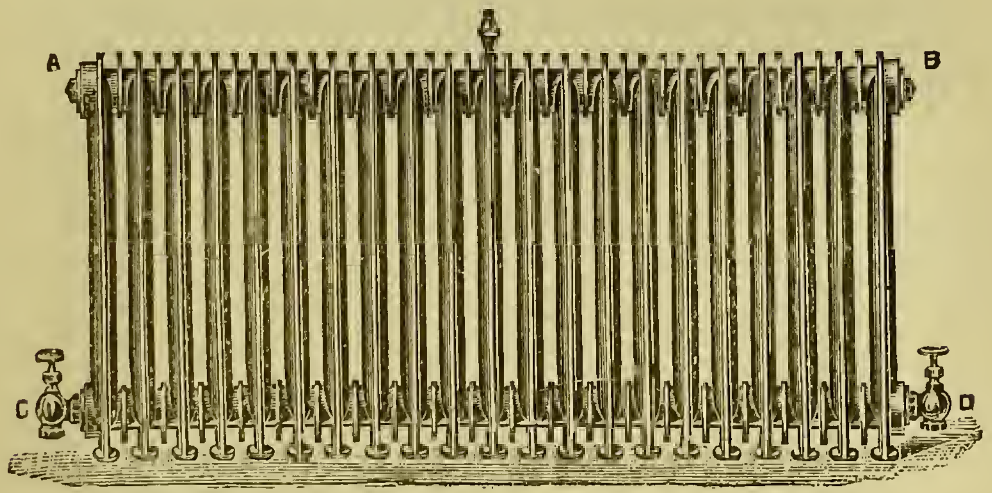

Fig. 204.

Fig. 204[*] illustrates the "Universal" radiator differing from others in being cast in one piece. It can, however, be had in a full variety of sizes. It is claimed by the maker that the absence of joints is a practical improvement. It is also made double or treble widthways, and in different heights.

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[*] Manufactured by James Keith, Holborn Viaduct, London.

Fig. 205 * is a neat pattern radiator made in all sizes. It is a somewhat severe design, as illustrated, but lends itself well to decoration. It is capable of very good treatment in this way. The section of pipes is a good one, admitting of rapid results being attained as they hold but a limited amount of water, and on account of simplicity of form can be easily kept

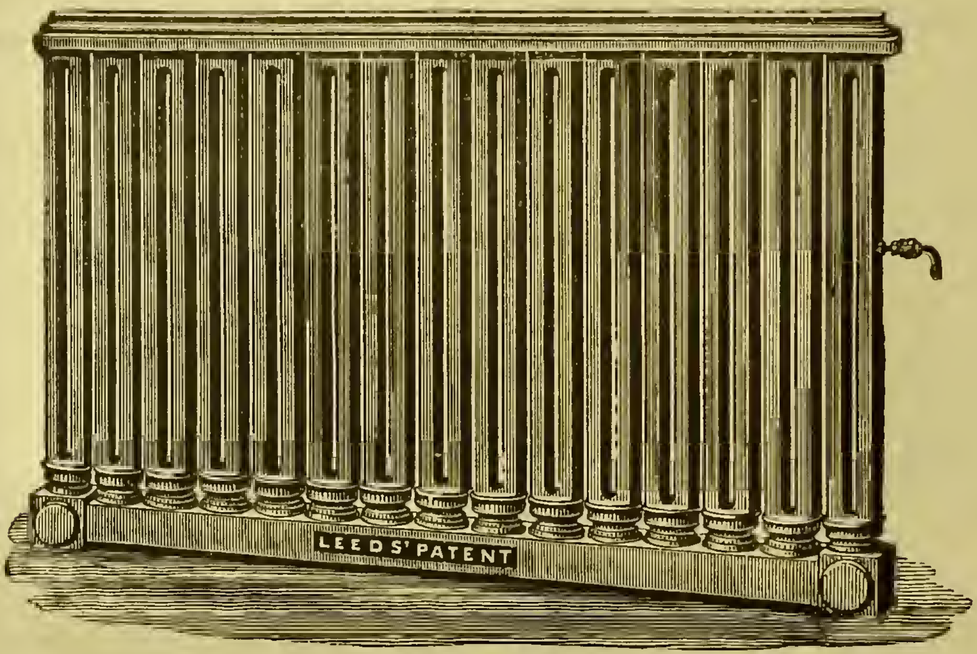

Fig. 205.

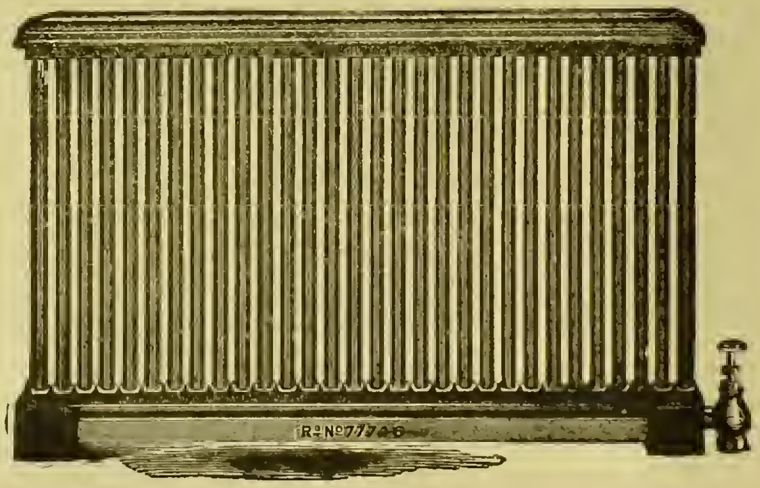

Fig. 206.

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* From the catalogue of Longden & Co., 447 Oxford Street, London ; and Sheffield.

quite free from dust. The tubes are screwed into the base, so there is little fear of any leakage, and the makers claim that the radiator stands on much less ground than other makes.

Fig. 206 * is another pattern that can be had either plain or with arrangement for inlet ventilation ; these upright pipes are of hexagonal section, and for ventilation the air-tube is passed right through each water pipe. This radiator is made in as many as 35 sizes, and can be finished bronzed and with polished brass moulded top, if desired.

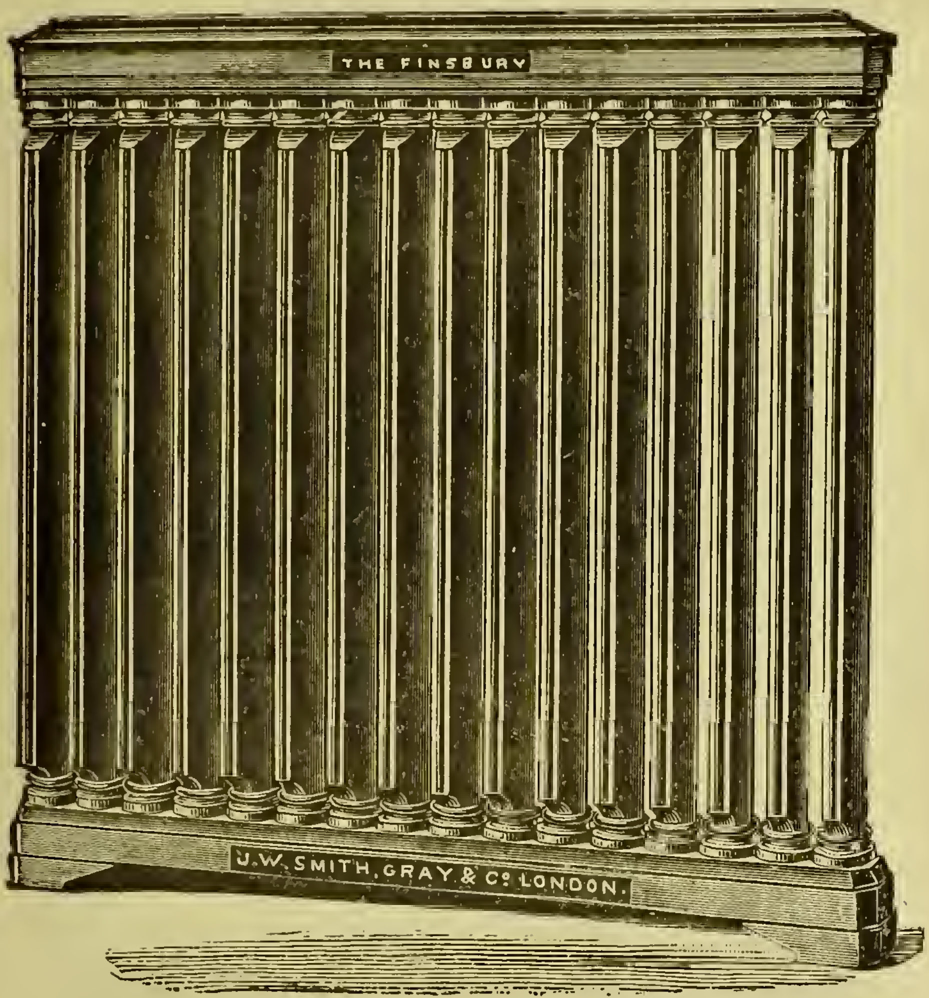
THE FINSBURY
J.W. SMITH, GRAY & C° LONDON.

Fig. 207.

Fig. 207 † is the "Finsbury" radiator. This has some design on the tubes with very neat effect. The design is arranged to increase the heating surface with the result that a radiator 3 feet wide by 3 feet high has a surface equivalent to

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* The Coalbrookdale Co., Limited, Victoria Embankment, London also Coalbrookdale, Shrops.

† Wontner, Smith, Gray & Co., Finsbury, London, E.C.

100 feet of 2-inch pipe. The floor space it occupies is 4½ inches from front to back. All sizes are made; round, square and angular forms can also be had. When required as a ventilating radiator the usual box base with regulator is provided, and an air-pipe is carried up through the centre of each hot-water tube.

Fig. 208 * illustrates a radiator of neat design, and which can be arranged as a ventilating radiator if required, There are internal air-tubes through each hot-water pipe, communicating with the box base, which can have a fresh air inlet in the usual way. The radiator is made in several sizes, and can be had with ornamental design on the tubes more suited for residence works.

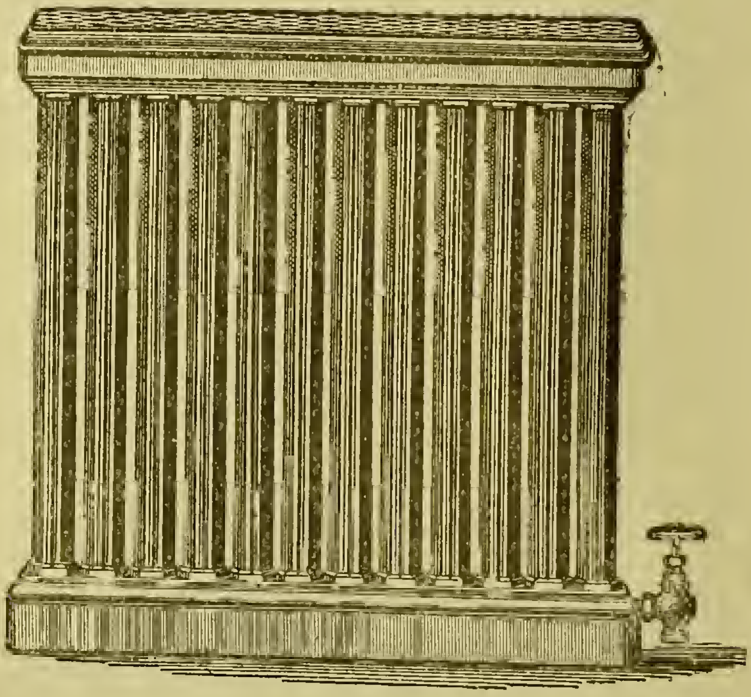

Fig. 208.

Fig. 209 † is another neat design, with fluted tubes; made in three heights, any length, and either 6-inch or 7-inch projection. It can also be had fitted as a ventilating radiator, with box base and air passage through each tube.

Fig. 210 ‡ is Messenger's new radiator, interesting as

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* T. C. Williams & Sons, London Street Iron Works, Reading.

† The General Iron Foundry Co., Limited, 5 Broken Wharf, Upper Thames Street, London, E.C.

‡ Messenger & Co., Loughborough, Leicestershire; and 163 Palmerston Buildings, Old Broad Street, London, E.C.

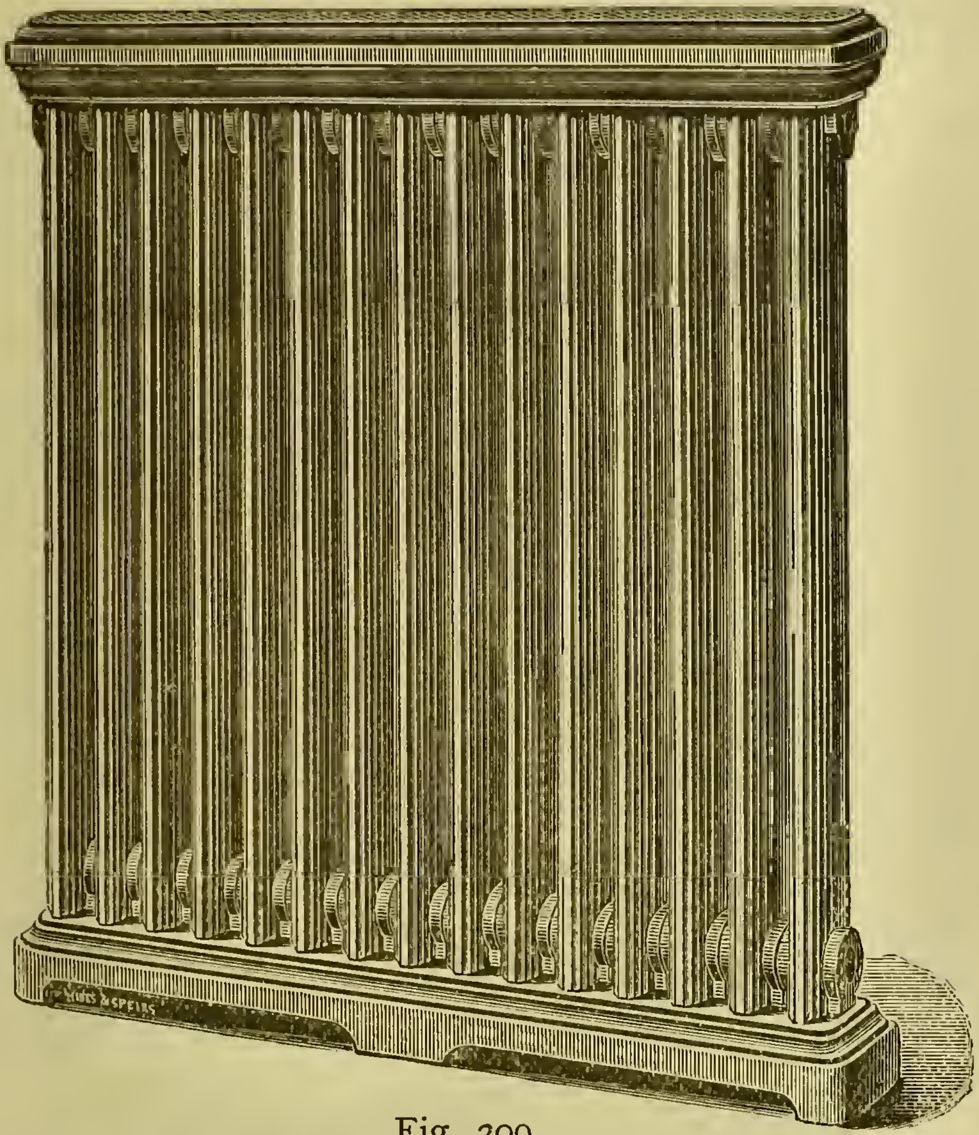

Fig. 209.

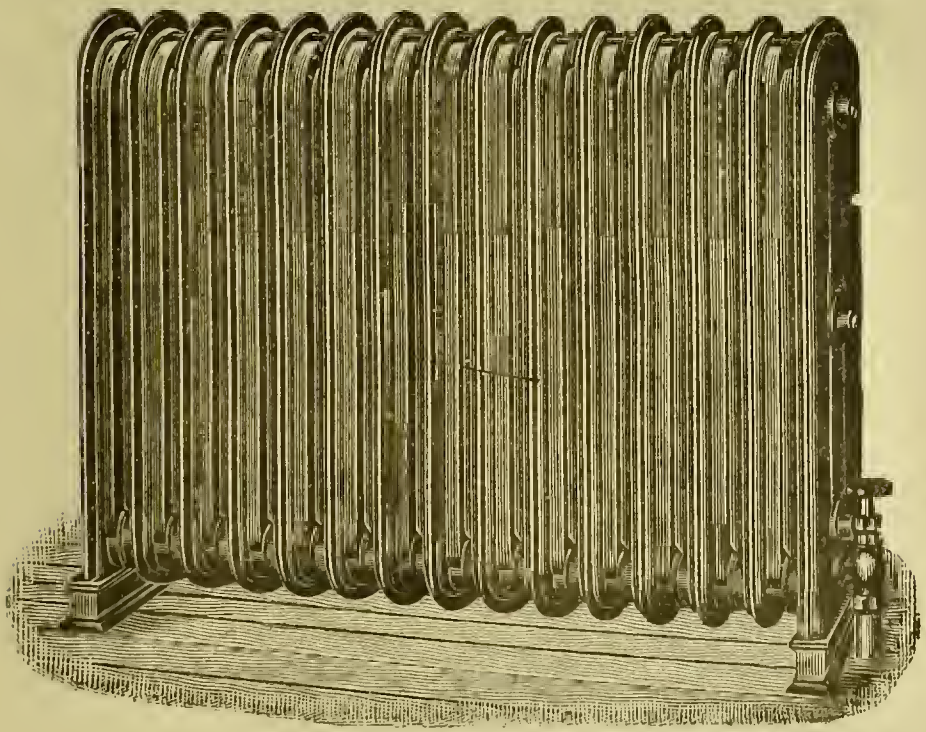

Fig. 210.

being the outcome of a premium offered for the best design. It is made either single or double tube (the illustration being of the latter) and several sizes of either can be had. It is an effective radiator, and spoken well of. Its appearance, for residence works, may not meet all tastes, but it is equal to the majority of makes in this respect.

Figs. 211 and 212 * are two more new radiators, being named the "Peer" and the "Count" respectively. The former, it will be seen, has plain surfaces, the latter being fluted. This radiator is of American design and built on the lines adopted in that country, but is entirely of English manufacture. The makers practically admit, what the writer has rather unwillingly to confess, that the American radiator is making headway in England, and it is from the manufacturers of that country that we can learn a great deal as regards heating appliances. This radiator is made on the latest principles, each section twice tested, also faced, drilled and screwed by machinery. The sections are jointed by right-and-left screw nipples, no bolts, rubber, or cement being used. Five heights, and many different lengths are made.

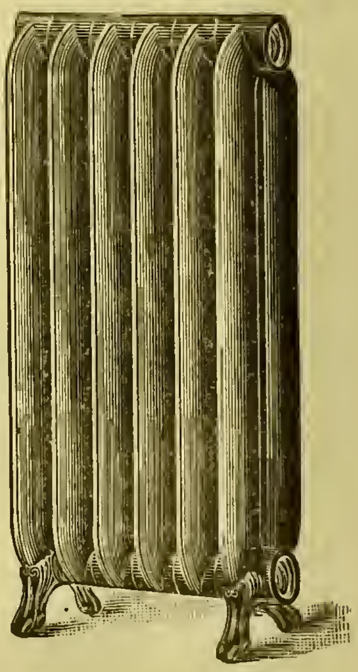
Fig. 211.

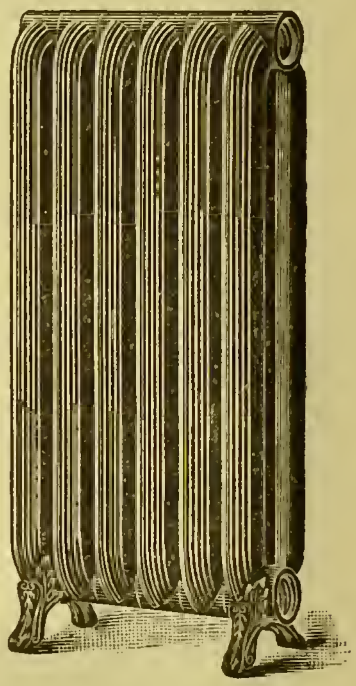
Fig. 212.

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* The Meadow Foundry Co., Limited, Mansfield, Notts.

Fig. 213 * shows a good form of ventilating radiator, introducing the use of ribbed or gilled pipes as illustrated. The air passage is between the front and back rows of pipes, with outlet at top and suitable provision for inlet at bottom. The inlet of fresh air is provided for by a passage cut through the wall and fitted with air-brick, as usual. The utility of the gills or external ribs to the pipes has been referred to (page 8, Fig. 1).

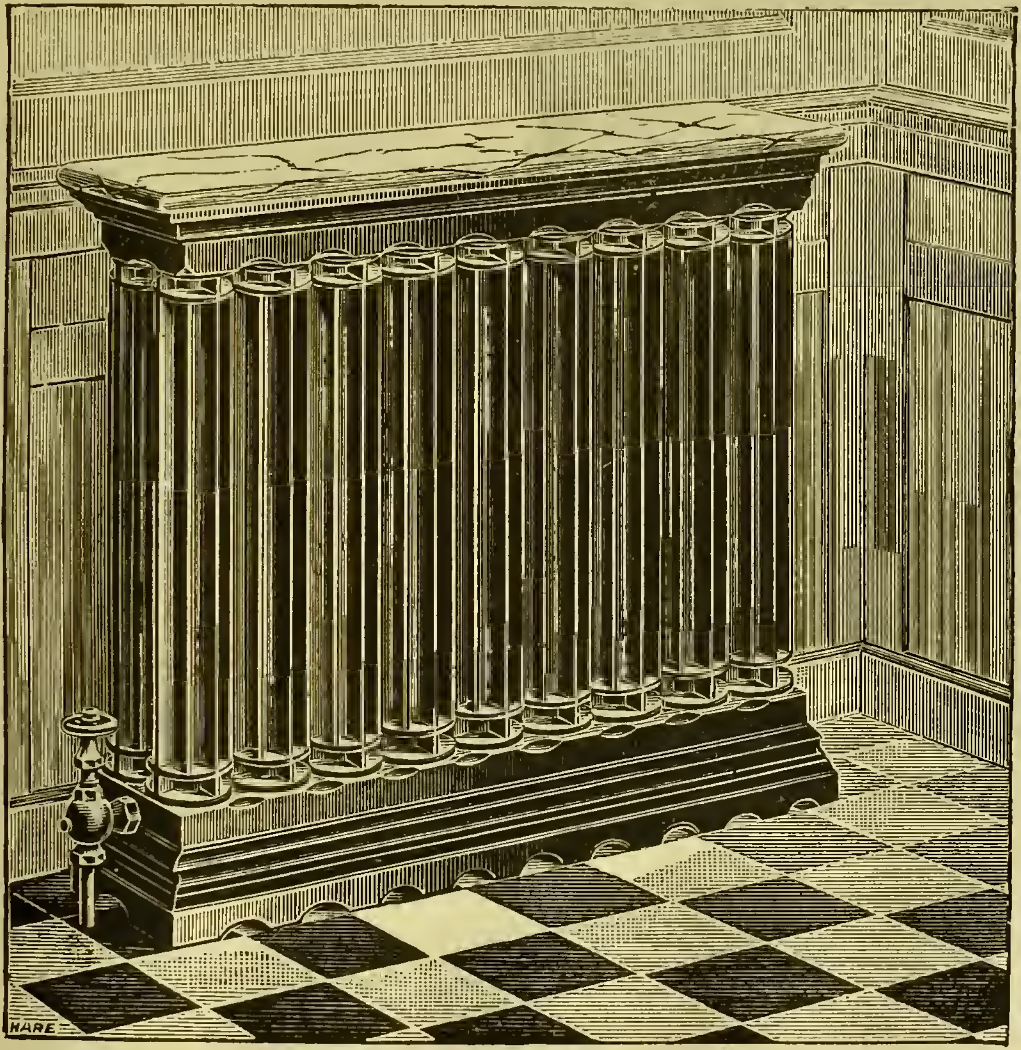

Fig. 213.

This radiator can be had with a single row of tubes, also square, round, and for corners. Five different heights are made, and almost any length.

Fig. 214 † is a ventilating radiator with air pipes passing

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* William Graham & Sons, 35 Upper Thames Street, London, E.C.

† The Meadow Foundry Co., Limited, Mansfield.

up through the water tubes from an enclosed base. The water tubes are of novel design, having much the appearance of bamboo. It is claimed for this undulating heating surface that radiant heat is projected in all directions, including the floor, and thus more equable results are obtained.

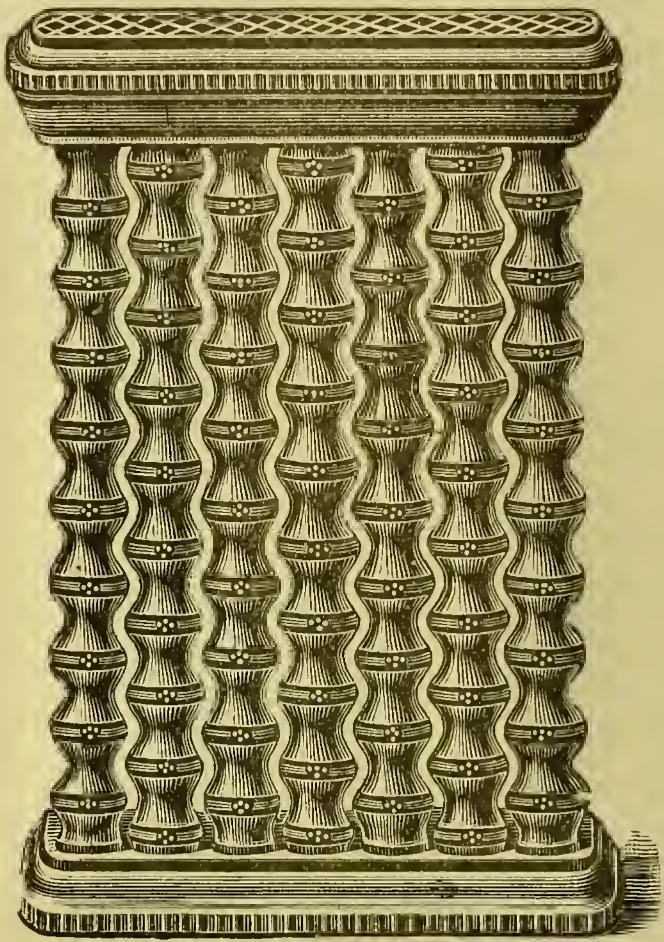

Fig. 214.

We have now to deal with the American makes of radiators, so far as concerns those which are stocked and regularly used by English engineers.

In manufacture the American radiators are as perfect as can be had at present, this arising, as a matter of course, from the greater experience due to the vastly greater demand they have. In America a radiator fulfils the purpose that a fire does in England, so that not only is the manufacture a trade of great magnitude, but they have to make radiators suited for residence work of all classes. This is where the English radiators so signally fail, their appearance quite barring their entry to the majority of residences. A few may be fixed in entrance halls, but it is very seldom that a house is heated throughout with the plain English radiators. Manufacturers probably consider that as the chief demand here is for institution work, schools, hospitals, municipal buildings, &c., where severely plain designs are preferred, that to introduce the "pretty" element would be to their loss. So far as it goes this is correct, but the American radiators are here, and if they do not make headway in institution work, they are certainly educating the English people to an approval of hot-water work that they never had before. The great future (and it is great) of hot-water work in England is in warming private residences, and this will never be effected with our present radiators. Money and artistic skill are devoted to making fire-grates as handsomely effective as is possible, yet a radiator which can be made more beautiful, is, at present, unsightly by comparison. It is quite hard to see the trade neglected and allowed to drift into foreign channels as it is doing at present. Radiators of fine design and appearance will have to be made in England in the near future, and the firm which acts on this first will secure much of the trade without trouble.

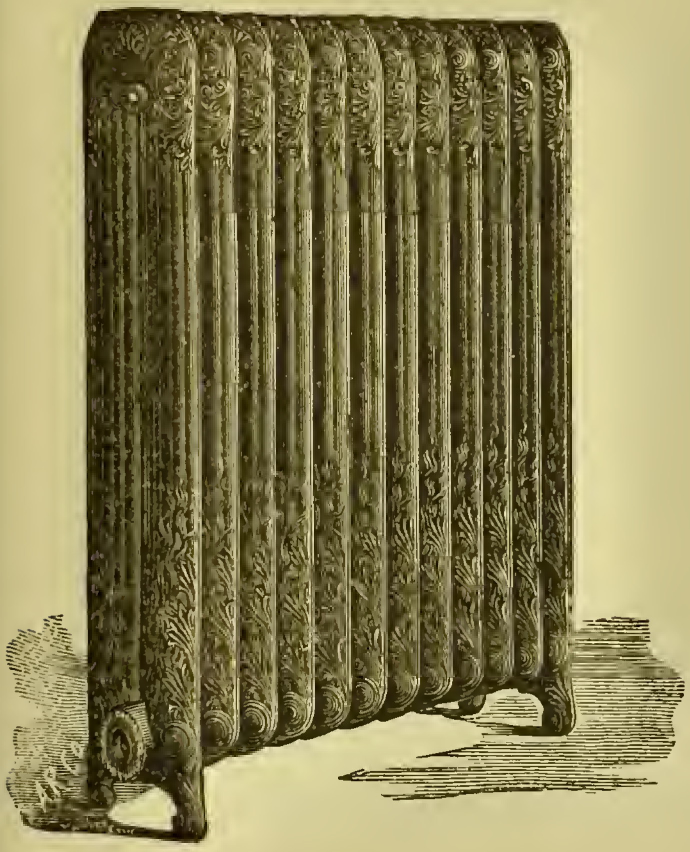

Fig. 215.

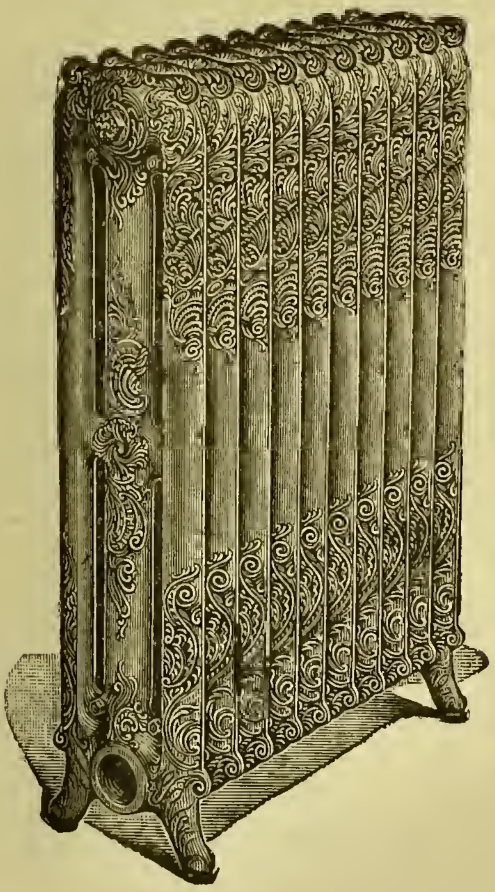

Fig. 216.

Figs. 215 and 216 * are the "Detroit ornamental fluted" and the "Rococo" respectively. The former is what is termed a two-column design, while the latter is a three-column, a column corresponding to what we might call a

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* The American Radiator Company, 143 Queen Victoria Street, London, E.C.

tube. They can be had also in single column and four columns, and these designs are only two of a large number made by this company. Nearly all American radiators can be had in irregular shapes—that is, with sloping tops to come alongside a staircase; with high ends and low centres to come under windows; in circular form to stand round pillars; in semicircular form to go against walls built on the curve; also extra low in height to go under window seats, &c. The casting of these radiators has a fine finish, and the ornamental part gives good results at the decorator's hands. The sections are jointed by right-and-left screw nipples. These radiators are made in six different heights, and any lengths that may be required.

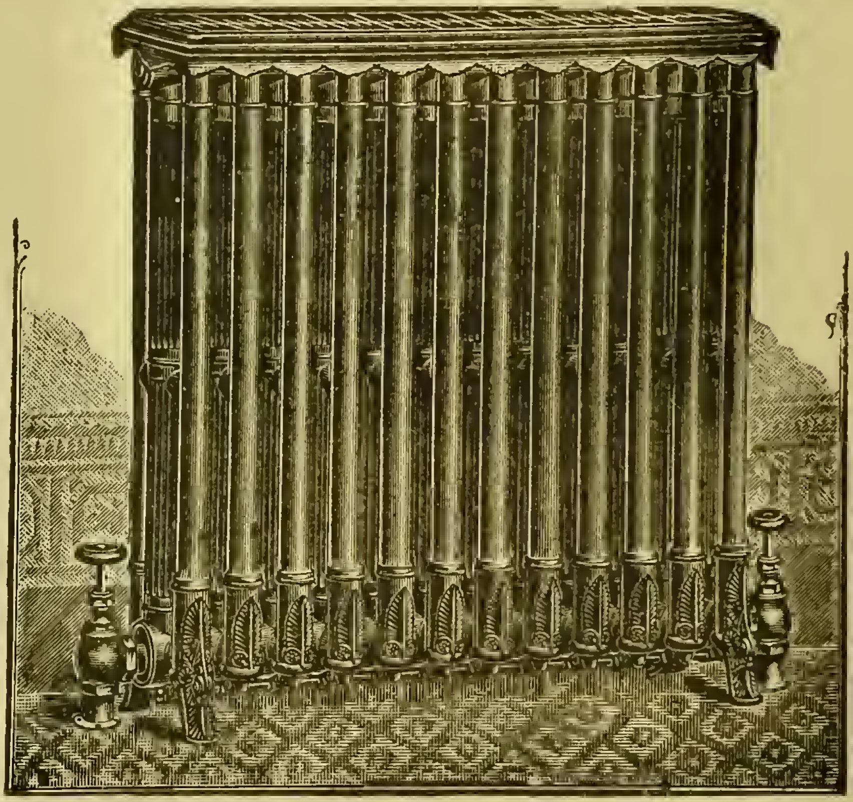

Fig. 217.

Fig. 217* is the "Union" radiator in plain design. This make of radiator can be had in three other designs of a more ornamental character. All of them are built on the same lines, each section, which is a single casting, consisting of an elliptic centre tube, with a smaller round tube on each side.

[*] H. Munzing, 199 Upper Thames Street, London, E.C.

These three tubes have communication at top and bottom, also across the middle, as shown. It is a very effective radiator, with large surface in comparatively small compass. Made in six different heights, and any length desired; also supplied as a ventilating radiator, when required. They are jointed up with right-and-left screw nipple joints.

Another radiator by the same firm is the "Coronet," Fig. 218, a more ornamental type, and having the character of what we might term the typical American radiator. It is a two-column pattern with very effective ornamentation.

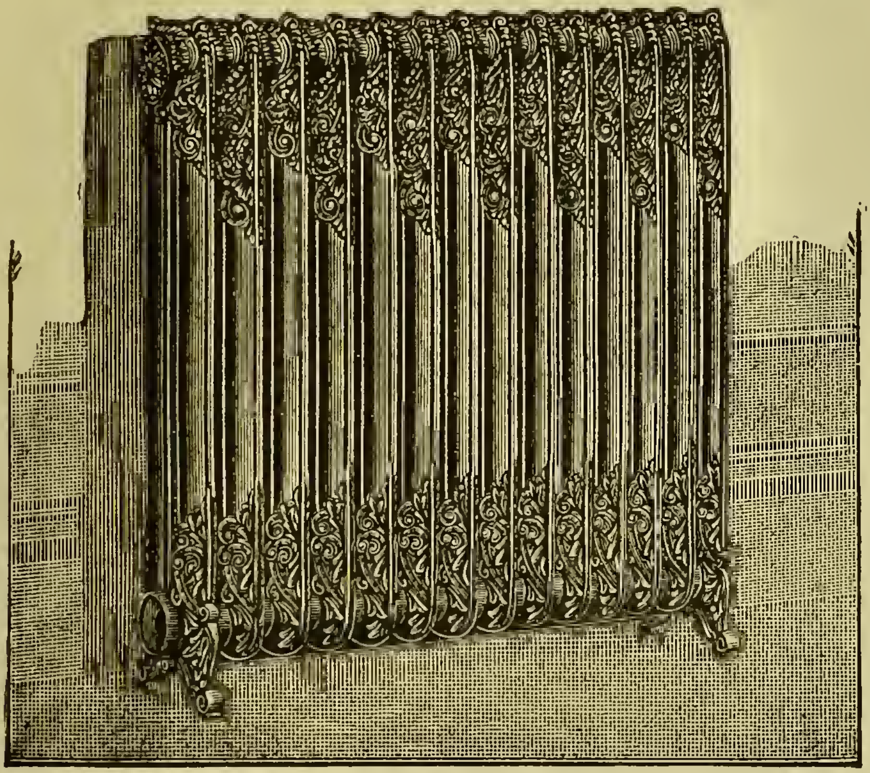

Fig. 218.

This is a narrow form of radiator, made to meet the wishes of those who require the radiator to have the least possible projection.

A peculiarity in the ornamentation of the upper part is that the design comes down about 10 inches on one side of every section, and about 8 inches down the other side. When jointing up the sections, the ornament can be made to come in alternate lengths, as illustrated, or all one length, or long at the ends and short in the middle; in fact, there are several combinations to choose from.

Another good example, and having a wide reputation in America, is the "Safford," Fig. 219.* These are made in several different designs, both plain and ornamental. Some have flattish oval tubes, others have the tubes more square, as that illustrated. Five heights can be had, in any length, and there are narrow and ordinary two-column, also four-column patterns. All are jointed by right-and-left screw nipples.

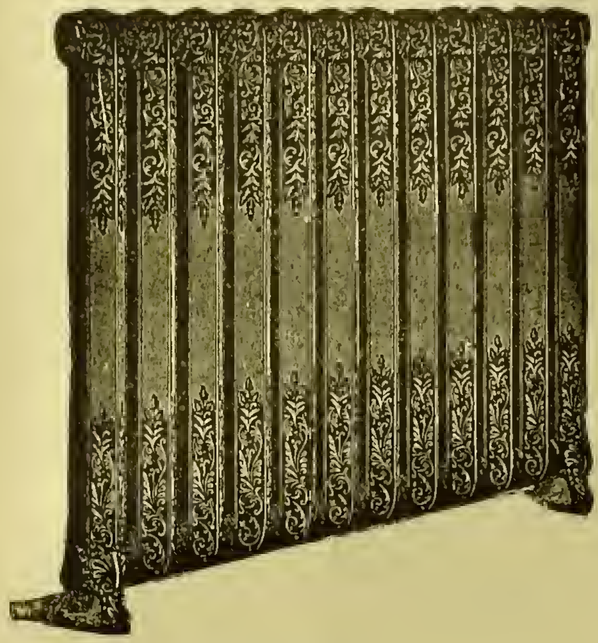

Fig. 219.

Figs. 220 and 221 † are introduced to show two more designs of American made radiators, these being, particularly the latter, something different to those previously illustrated, and showing what a strong competition the English makers have in radiators for residence work. Fig. 221, the "Dysart," is considered to have a very effective appearance, the ornament standing boldly out, this ornament being the design and modelling of an Italian artist of some repute. It is a design that gives much the appearance of porcelain, when the radiator is enamelled. All these are jointed with right-and-left screw nipples, and are made in several different heights and lengths.

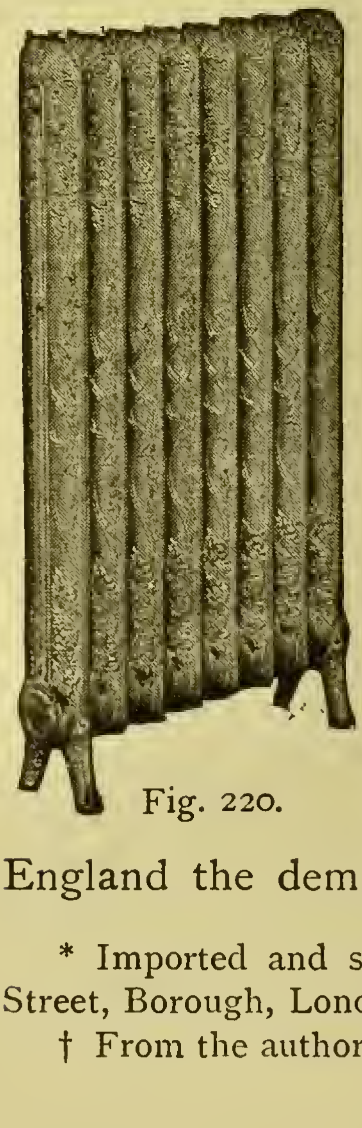

Fig. 220.

Why radiators have never been made in brass is difficult to understand. In England the demand has hitherto been rather slow, and this is a reason in itself; but in America, the home of the radiator, it would be supposed that a brass radiator could not fail to sell largely. There are palatial houses and hotels where brass would be preferred in every case, but the writer has every confidence in stating that they have not been made yet. Even an instance of a brass radiator made to order cannot be traced. Iron radiators will bear good decoration if delicate colours are used. In America, bronze powders of all colours are largely adopted for this work, but at the best they cannot approach well-finished brass.

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* Imported and stocked by Hayward Brothers & Eckstein, Union Street, Borough, London, S.E.

† From the author's catalogue.

The writer has some brass radiators now being made to his designs, but they are not advanced enough to warrant their being illustrated and described here. There is every possibility that their introduction will do much to make hot-water heating more favourably looked upon in well-furnished houses, and there is also a probability that other manufacturers will be induced to follow the example set them.

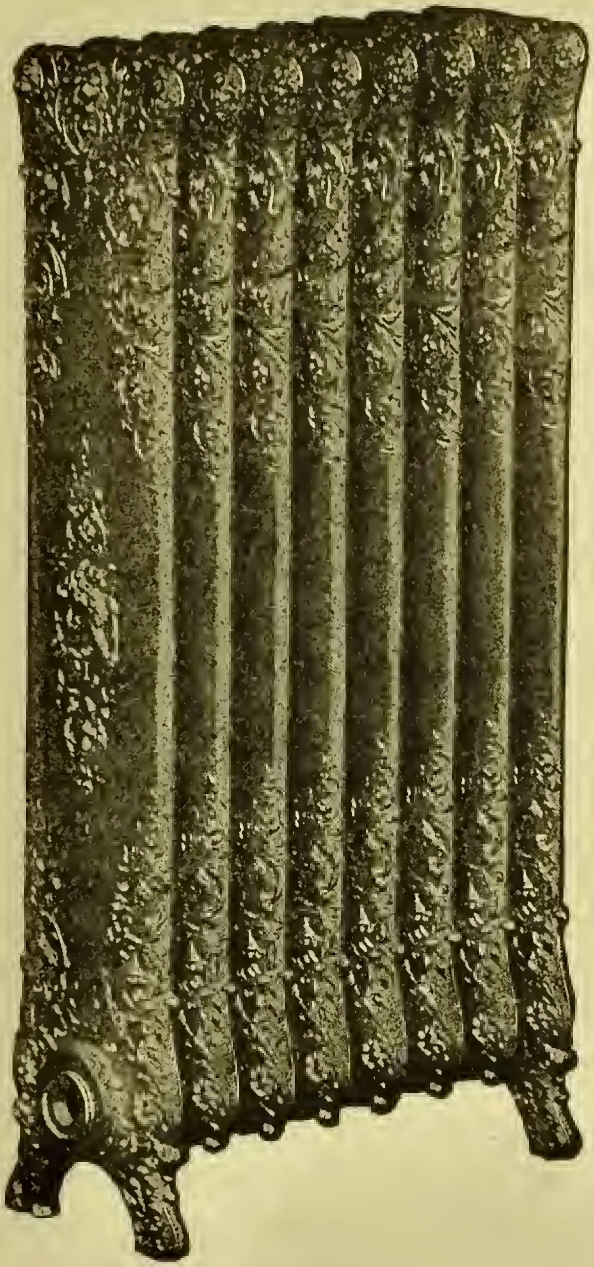

Fig. 221.

CHAPTER XVII.

QUANTITIES FOR BRICK BUILDINGS.

Hood's rule and suggestions, and their application—Calculations of cubical capacity—Varied circumstances to be considered—Tables for rapid calculations.

HOOD was unfortunate in adopting his rule, p. 161, for living rooms and public places, by allowing five cubic feet of warmed air per minute to each person occupying the place when it had its full complement of people in it. This allowance, as a rule, was insufficient, and very uncertain, and Hood recognised the fact, as in a later paragraph he points out that the rule does not allow for variation in cubical contents. Accordingly, he compiled a Table for rapid calculation based upon cubical contents; but one or two authors go to quite unnecessary lengths to point out and dwell upon the fault of the rule referred to, ignoring the fact that Hood pointed out the fault very clearly himself.

It will be quickly recognised that allowing so much air per person will hardly suffice, for if we take ordinary living rooms, how these vary in size in one house, yet the same number of people use them all or many of them. And the quantity of pipe for one room would not be suited for another room if their sizes disagreed to any noticeable extent. Or, if we speak of a church, this may be the same length and width as a lecture hall, but there would probably be a great dissimilarity in height. We can get more exact results by calculating upon the wall and window surface.

Rapid calculating tables are now usually based on the capacity of a room, allowing so much pipe for 1000 cubic feet of air, the quantity of pipe varying in ratio with the temperature required. As, however, we spoke of a want of exactness in Hood's rule, it is necessary to point out that no desirable degree of exactness attends this method, for circumstances vary so greatly, the variation, however, being chiefly confined to position, and to quantity of glass, as the cubical contents tables are based upon the existence of very little glass ; also upon the position of the room or building being normal, that is, not very exposed, not naturally damp, and that which lends itself to being heated successfully. The table now about to be adduced is therefore only to be adhered to when the conditions are what may be called normal : no particular exposure to bleak winds, no persistent dampness, no unusual degree of ventilation (except in drying closets, where free ventilation to carry off moisture is as needful as heat, but which is allowed for), and particularly no unusual quantity of glass, windows, or lights, &c. If any of these irregular conditions exist allowance must be made for them ; no rule can be laid down as to the degree of allowance needed ; it must be left to the engineer's judgment,* and if in doubt, let the error be on the side of too much rather than too little pipe.

The following table is based upon the temperature of the water in the pipes being about 180° F. and the coldest external temperature being 20° F. The quantities can be considered correct under ordinary conditions, but care must be taken to see that no unusual circumstances exist ; if they do more pipe must be allowed, and this allowance should be liberal, to secure the best results. As this table represents very nearly the least quantity of pipe that will do the work, it is better, when possible, to increase the amount even up to 20 per cent., particularly when the apparatus is attended to by a person who has many other duties to perform, and may not give proper attention to the fire, by which the heat of the water in the radiating pipes will be kept up to 180°. The quantities given are for four-inch pipe (one foot being equal to a square foot of surface*); for three-inch pipe add one-third to the quantity, and for two-inch pipe double the quantity.

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* The writer had occasion to heat a room about 20 feet long by 18 feet wide, in which there were three windows, averaging 9 feet by 7 feet (high casements), one window on each of three sides, as this room projected out from the main building. The room faced the north ; and what with the exposure and the quantity of glass, double the regular quantity of radiating surface was only just successful in heating the place when the weather was very severe.

To keep these latter high temperatures the boiler requires different and proper attention, as the water should be kept nearly at boiling point. Pipes in channels or trenches covered by a grating, or partly enclosed in any way, must be increased in quantity by 20 per cent. to attain the same results.† When

TABLE OF HEATING SURFACE FOR CUBICAL CONTENTS. NO. 1.

(For boilers regularly fired.)

Temperature required.	Quantity of 4-inch pipe required for every 1000 cubic feet capacity in a brick-built apartment or building.	Some of the uses for which the temperatures may be required. The different uses varying the quantities.
°	feet	
50	6	Coach-houses, &c.
55	7	Stores, workshops, &c.
60	9	Churches, public places, shops and sleeping apartments.
65	12	Living rooms, &c.
70	15	Lobbies, entrance halls, or wherever the cold air first enters the building.
70	30	Drying rooms for paper, herbs, &c. &c., to which there is free ventilation. This temperature when empty and dry.
75	40	
80	53	
85	65	
100	110	Drying rooms for very damp substances, for drying linen, general laundry work, &c. Full ventilation. This temperature when empty and dry.
110	140	
120	180	

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* See footnote to page 161.

† This is an allowance nearly always necessary in church work, unless exposed radiators or pipes are used, and it also occurs frequently in living rooms, when even the best radiators may be objected to, and coils have to be placed beneath the floor.

TABLE OF HEATING SURFACE FOR CUBICAL CONTENTS. NO. 2.

(For vertical and similar boilers which are charged with fuel to last several hours, and worked with a slow draught. Chiefly residence works.)

Temperature required.	Quantity of 4-inch pipe required for every 1000 cubic feet capacity in a brick-built apartment or building.	Some of the uses for which the temperatures may be required. The different uses varying the quantities.
°	feet	
50	7	Workshops where active work is carried on, also coach-houses, &c.
55	8	Stores, workshops, coach-houses, harness-rooms, &c.
60	11	Churches, lecture-halls, schools, shops and bedrooms.
65	14	Living rooms, hospitals, &c.
70	18	Lobbies, entrance-halls, or wherever cold air first enters a building.

air is warmed before it enters, by contact with pipes in closed channels or chambers beneath the floor, a greater allowance of surface is needed. But this will be spoken of more fully hereafter.

As stated, these tables can only be considered approximate in quite a wide sense of the word, and every engineer has to give thought to several things that may vary results. Doubtless the chief cause of irregularity in these works is the quantity of glass. In horticultural works the glass is the main, in fact the sole cooling influence considered, and it should be the same in brick buildings. Although the quantity of glass is less in the latter, it varies to a much greater extent than it does in glasshouses. With every house the architects commonly seek to make the exterior appearance symmetrical, and to do this it is quite usual to have windows of equal area and shape to rooms that are totally different in size within, and this makes a noticeable difference in the heating. Walls lose heat, and there are leakages of cold air into rooms, but in quite the majority of cases it is the glass that cools the air most.

On this account the area of glass should always figure in the calculations made for heating surface, and a good plan would be to work out the amount required as follows :—

> Allow 1 square foot of heating surface to each 3 square feet of glass, with the addition of 6 square feet of heating surface to each 1000 cubic feet capacity of the room.

This rule is for a slow draught, but will only afford one temperature, viz. that suited for living rooms ; and, although it will give correct results, the best possible plan is to let it check calculations by the other table, so as to expose unusual glass surface if it exists. Extra allowance is still necessary for very exposed rooms, or special conditions, as with other means of calculation.

CHAPTER XVIII.

EXAMPLES OF LOW PRESSURE APPARATUS FOR BUILDINGS.

Radiator heated from grate fire—Two radiators heated from independent boiler—Method of heating two rooms with details of radiator connections—Coils encased under floors—Heating a residence, with plans of ground floor and basement—Heating three corridors; two methods—Heating four floors of business premises—Horizontal branches—Church work.

It is proposed to adopt the same method with these examples as with those given in horticultural works—viz. to give the varied ways of carrying out the work, commencing with the smallest. There is a wider scope for examples in this case as, not only do the buildings vary more greatly in size and character, but there are several distinct systems of apparatus used in buildings of this kind, whereas, with horticultural works, there is but one system generally adopted. Examples of small works are given, as works of a limited size are quite common, especially in residences. As previously mentioned, the examples do not represent anything that can be copied, as the conditions are rarely precisely alike, but the correct principles are embodied, and in this respect should prove useful. To those practically unskilled in the work, examples are of great value and interest always. There is so much instruction conveyed by a detailed illustration, and the written information is rendered more complete by this means.

Fig. 222 illustrates a little apparatus that is frequently fitted with the object of affording some warmth to a room adjacent to that in which the fire is. This may be a library or study not having sufficient use to need a fire being kept up regularly, yet which should not be without warmth. Sufficient heat can also be obtained in this way to keep a small billiard-room from becoming very cold, though it would not suffice to make it comfortably warm, except on the mild winter days.

This illustration represents a three-pipe coil of $\frac{3}{4}$-inch pipe, placed at the back of an ordinary living-room grate fire, the pipe continued from there to a radiator or short length of hot-water pipe in the adjacent room in question, in a manner something similar to that shown. The top pipe of the coil is continued as a flow pipe, and the lower is connected with the return. Two unions are inserted at the points shown just above the coil, so that the latter can be disconnected and taken out, if desired, without disturbing the grate or the general service pipes. It may be necessary to take the coil out at some time, as no means can well be provided for cleaning it, and the accumulated sediment would eventually bring about its destruction. Under ordinary conditions the coil should last in good order for, say, five or six years, provided it is of good steam quality tube.

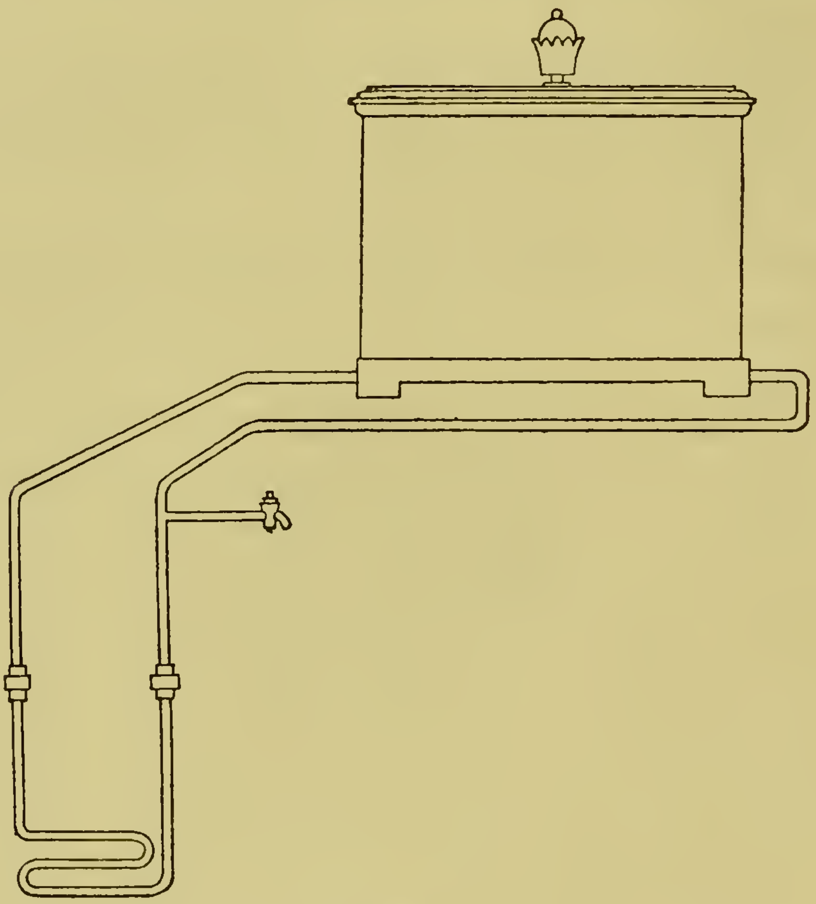

Fig. 222.

The amount of work this little coil in the fire is capable of doing cannot well be fixed, as it will depend entirely upon the size of the fire and the way the fire is attended to, but a fire-box 15 inches wide, which holds a good body of fuel, wholly surrounded with fire-brick (an important feature in keeping a very hot fire), will successfully heat from twenty-five to thirty-five feet of radiating surface. This, however, brings us to consider what is sometimes a drawback to this arrangement, and what limits the size of the coil, as otherwise a larger coil could be used with proportionately greater results.

In introducing a coil of water pipes into an open grate fire we bring about a cooling influence, so that, in the case of a small sized or thin fire, holding but a small body of fuel, we have the greatest difficulty in keeping the fire alive. And supposing the fire can be kept going, that part around and in contact with the pipes will be deadened and nearly black, the fire itself losing its cheerful appearance, and the heat contributed to the pipes will be but little. If the fire is of good body these drawbacks still exist, but in a much reduced form, and the application is practical. In limited sized grates, even with deep fires, it is better to reduce the size of the coil to two pipes; and even one pipe passed straight through the lower part of a fire at the back will heat a small radiator, supposing only a small amount of radiating surface is needed. A small radiator could be used to *assist* in heating a large room which was not quite sufficiently heated by its own fireplace.

It will be understood that the deadening effect a coil has on the burning fuel is not only due to the great heat absorptive power of the water, but we may say chiefly to the fact that the description of grate referred to *is an open one*, and *not a closed stove;* with the latter much greater results can be effected; see coil boiler, p. 213.

This apparatus requires some arrangement for filling; the illustration shows a vase-shaped vessel on top, which can be fitted to act as a filling cistern, and will serve as an air-vent also. It would be desirable, however, to have an air-cock at some other high point on the radiator, to allow free vent for the air when first filling; it might not be needed afterwards. If the fire is a very large one 1-inch pipes may be used with increased effect, or, if so small that only one straight pipe through can be allowed, this might be 1 inch. In any case they should rest against the back brick and be low down in the fire. The illustration shows the radiator behind, and above the level of the fire. If it was on the same level the pipes would have to be carried sharp through the brick behind; this would not be quite so simple, but facilities could still be arranged for disconnecting on the other side of the wall.

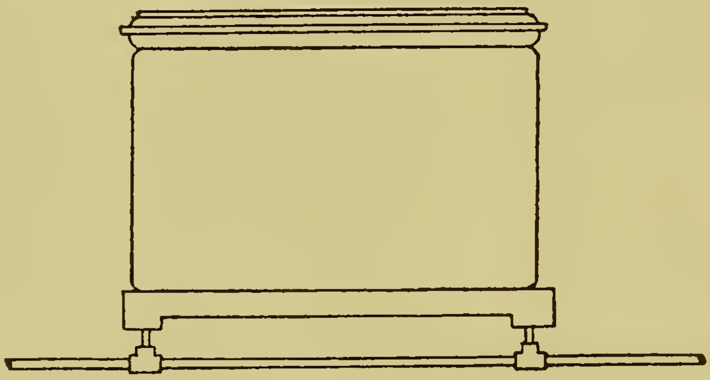

Fig. 223.

It might be mentioned here that all coils and radiators can be connected in through the bottom at each end, as Fig. 223, if desired, and by this means no portion of the connecting pipes will be visible, the mains or branch mains passing beneath the floor. This cannot always be done conveniently, neither is it always a good arrangement if there is a stop-cock to the coil, as there would be no place for the cock to be put in sight. The cock, however, could be worked by a key through a hole in the floor.

The next illustration, Fig. 224, is an apparatus on just a little larger scale, and which would most probably be worked from a small independent boiler.* This represents two full-sized radiators (or stacks of pipe if desired, which, however, would have to be encased or hidden) in a large entrance hall. The positions would be fixed by various conditions, staircase, doorways, &c. If fitted with marble tops, radiators can be used as tables for visitors' hats, but it would not be desirable to utilise them for this purpose if they have iron tops, as the heat might affect the shellac material of which the hats may be partly composed.

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* Sometimes one or two small radiators can be attached to a domestic supply apparatus. See Domestic Hot-Water Supply.

These two radiators are supposed to be exactly on the same level, but one is further away from where the pipes come up through the floor than the other, but if the difference in distance is not very great there is no need for stop-cocks. A trifle more rise to the pipes leading to the distant one will equalise their working, and this rise can generally be arranged without difficulty. If possible, it will be best, as every engineer understands, to carry the horizontal service pipes * along beneath the ceiling of the floor below, and not just beneath the floor boards upon which the radiators rest. This latter way would probably involve cutting the joists a great

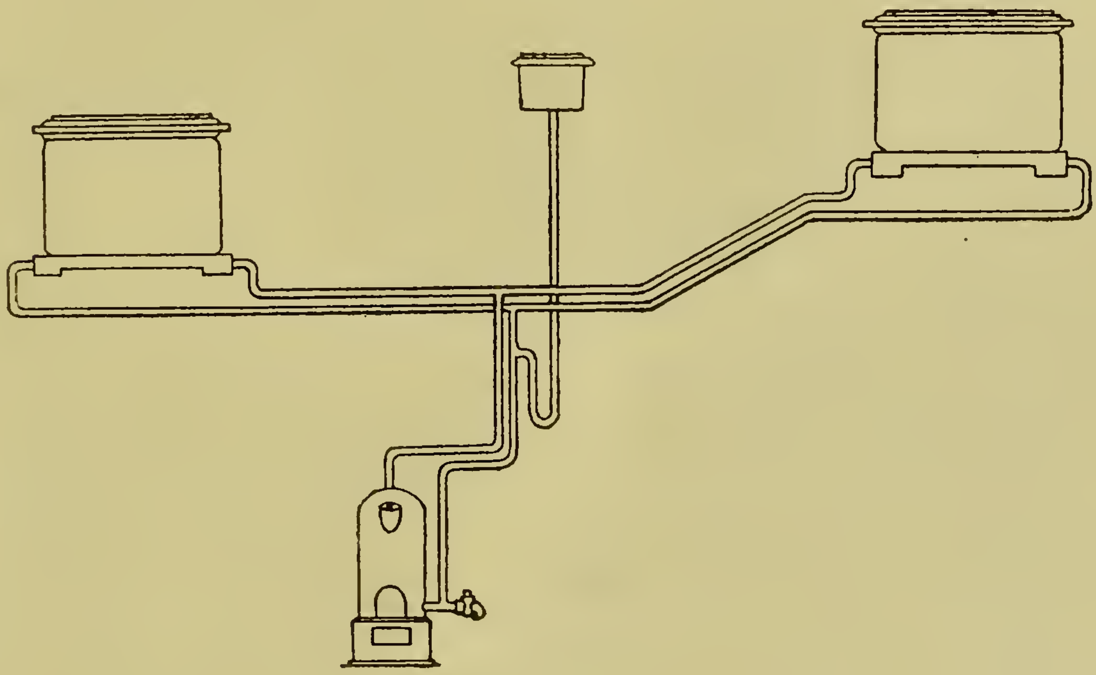

Fig. 224.

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* As mentioned in horticultural works, horizontal pipes are spoken of as those which are carried nearly horizontally ; there should be, correctly speaking, no pipes in these works that are exactly horizontal.

deal, would admit of but a trifling rise to the pipes, and entail much more work. If it is desired to give one radiator a better rise in the pipe than the other (both radiators on the same level) it can be effected as Fig. 225. This could be very easily done in running the pipes along the ceiling below, assuming it is only cellars or kitchen offices there.

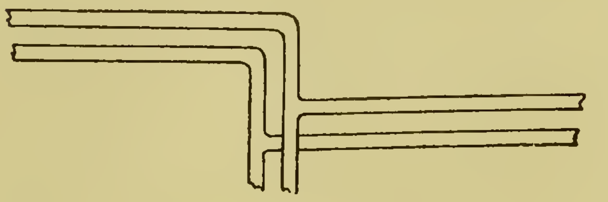

Fig. 225.

The cold supply would have to be provided for by a small cistern. This could be placed in a cupboard, or in any out-of-the-way corner, but it need not be more than twelve inches above the radiator tops unless it be desirable to put it a little higher to get it into a non-conspicuous position. It may be connected into any of the return services, but there should be the necessary dip or inverted siphon somewhere in its length (see p. 54), as near as possible to where it is connected into the return pipe. And the less length the cold supply pipe is the better, to avoid the unnecessary cost and the risk of stoppage by accumulated dirt. The cistern should have a cover to keep dust from entering. Each radiator requires an air-cock.

The pipes in this apparatus might be 1¼ inch from the boiler to the junction, and 1 inch from there to the radiators. These sizes would be quite effective, but unless the distance was very short, or lowness of cost was of importance, the pipes from the boiler to the junction might better be 1½ inch. The very smallest boiler would probably be found sufficient for these.

Fig. 226 shows a little larger apparatus which we may suppose heats two rooms of unequal size, somewhat widely separated, so that the service from one could not be continued across to the other. Separate services have, therefore, to be carried to each, the boiler being situated somewhere between. In this apparatus, as in the two last, the rooms to be heated are only a few feet above the boiler. This, however, makes

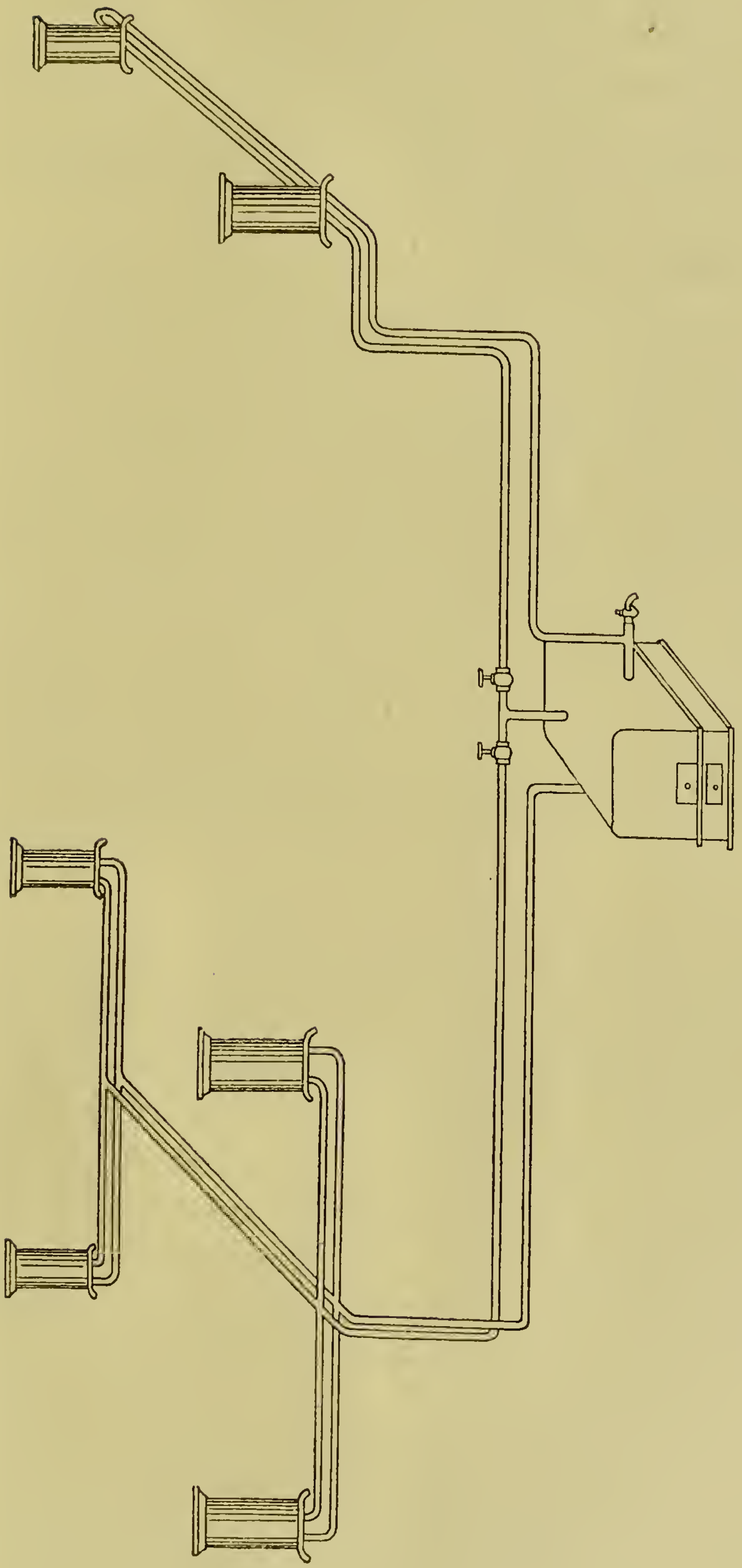

Fig. 226.

Apparatus designed to heat two rooms of unequal size, both on the same floor, just above the boiler, but situated a little distance apart, the boiler coming centrally between them. The room on the left with four pedestal radiators is a large one—a billiard-room, for instance—that on the right being smaller. The cold supply service, and expansion pipe, are not shown.

no difference in the actual working of the apparatus, and if the rooms were two or three floors above the boiler the arrangement would be carried out the same, except, perhaps, that with a low apparatus we might use a little larger pipe than otherwise, first, as the motive power is less, and, secondly, as a difference in size does not make a great difference in cost when the quantity is limited.

In the preceding apparatus (Fig. 224) the flow pipes were shown entering one end of each radiator, and from the other ends returning to the boiler. Now, this principle can usually be adopted only when there is a distinct service pipe to each radiator, as there shown, and as also shown in the left-hand room in this apparatus; but in the right-hand room the two radiators are shown both directly connected with the main.

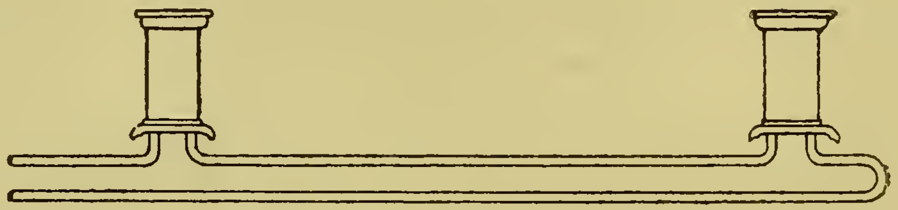

Fig. 227.

If we cause the water to pass through one radiator before it can reach the next, as Fig. 227, we must expect this latter one to be longer in becoming hot, and although there is, as a rule, no grave objection to doing this with just two radiators, it would certainly be objectionable if there were more than two. If there were, say four, as in the left-hand room, the last one would probably come poorly off for heat, this depending, however, upon the size—i. e. the radiating surface and contents of each radiator. If they were of fair size most unequal results would be caused.

As just mentioned, there is a distinct branch flow and return service to each radiator in the left-hand room, and they would be connected as in the apparatus shown preceding this (Fig. 224). In the right-hand room the radiators should be connected differently, as Fig. 228, the flow pipe rising into, and then proceeding from, each radiator, but without stopping the free passage of water through the main flow which passes beneath them.* If preferred, the connections could be made to the return, instead of the flow; the same results would be obtained in either case in this instance.

Sometimes the radiators are connected to both flow and return, as Fig. 229; this, in the writer's opinion, is not the best practice.† The objection is not so great, perhaps, with two radiators, but in a long straight run of horizontal pipe with several radiators in connection with it, the circulation has commonly been known to "short circuit," that is, to circulate through the first and second coil, leaving the water beyond this point in effect stagnant. There is every facility for the water to circulate through one coil and return to the boiler to the prejudice of those beyond it, if any incidental circumstance inclined the apparatus to act in that way. With the method of connecting wholly to one pipe, this result is

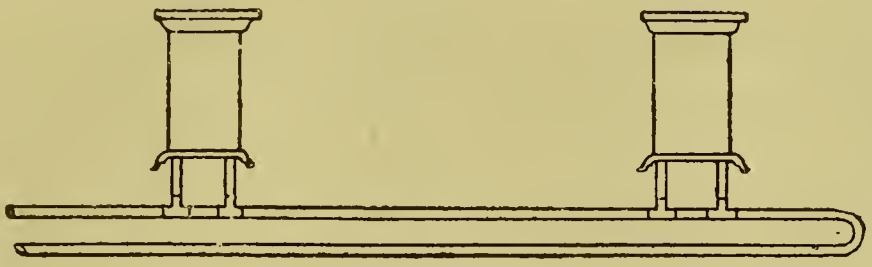

Fig. 228.

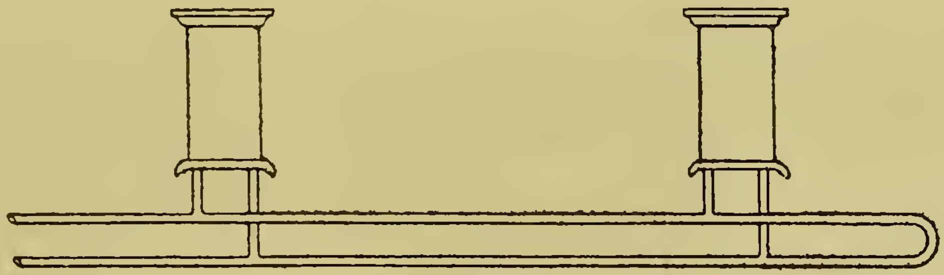

Fig. 229.

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* This is the "one-pipe" system of connection. This system of apparatus, which has much to commend it when the conditions are favourable, will be found fully described a little further on.

† This is the older "two-pipe" system of connection, which is also described fully later. It is not well suited for horizontal work.

impossible, and there need be no fear of the water not heating in the radiators, as you cannot anyhow get cold water to rest above hot water if there is free communication between the two. This argument will not apply so strongly when the mains or services which are connected to the radiators are vertical (not a common occurrence), as will be gathered from the examples that follow this.

In the example under discussion there is no need to put stop-cocks to each radiator or coil, the four in the left-hand room, although it is just possible they may start heating a little unequally, will, when in full work, act regularly and satisfactorily. The same remark applies to the two on the right. There is, however, a necessity for stop-cocks, one in each main flow, to divert the circulation in either direction as required, or in case one direction acted too freely and the other too sluggishly, as is very possible, particularly if on one side the apparatus extended a floor higher than on the other. The best and most convenient place for these cocks would be down by the boiler, as shown.

If desirable or necessary, the main in the left room could be run all round instead of up the centre, as illustrated; the radiators would then be connected, as Fig. 228.* If the room was very large, as we may suppose, the radiator that first received the hot water might be placed in the coldest part of the room, if the room was colder at one part, or had draughts entering at some point. It should also be mentioned that if either of these rooms were living apartments and highly decorated, the best of radiators might be considered unsightly. In this case they, or plain coils, can be placed under the floor in boxes.

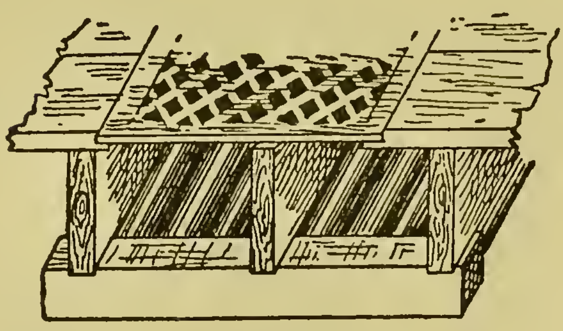

Fig. 230.

In placing coils in boxes they would be braced up to the joists which support the floor of the room to be heated, as Fig. 230, as it is supposed that no provision has been made or exists for the coils to come immediately below the line of floor boards (by trimming a space within the joists), and that no provision exists for running pipes beneath the floor in a straight line with gratings over. With a coil against the joists as shown, the box* forms a projection on the ceiling underneath, which is only admissible if this lower room be very unimportant—a kitchen or servants' office. If it should happen to be a kitchen the box must be *quite* air-tight or the odours of cooking will be upstairs with great rapidity when the apparatus is hot. A grating (brass for preference) must be let into the floor of the room to be heated, and this grating should be of good size, it having to act both as an inlet and an outlet to the air that is warmed, and its pattern should be as open as possible, and strong to bear walking upon. The box could be arranged for admission of fresh air if desired. In every such case it must be remembered that radiating media beneath floors, &c., are of less efficiency than those exposed.

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* This branch would then be carried out on the "one-pipe" system, as will be seen directly.

The coils that lie on their sides beneath floors must be slightly tilted, the pipe connections being made at the lowest point. They must also have the necessary air vents, but these may be small pipes carried down to the floor below, terminating with a cock, which, of course, will allow of the air being discharged in the same way as if the cock was screwed directly into the coil.

The cold supply would be provided for by a fair-sized cistern, placed at any point just above the highest radiator, and connected into any of the returns with the necessary dip. Air cocks must be fitted to every radiator, and in an apparatus of this size (and in the preceding one also, if convenient) an expansion pipe of, say, 1-inch pipe, should be provided; off the main flow, just over the boiler, would be a good place; this pipe extending to above the level of the supply cistern.

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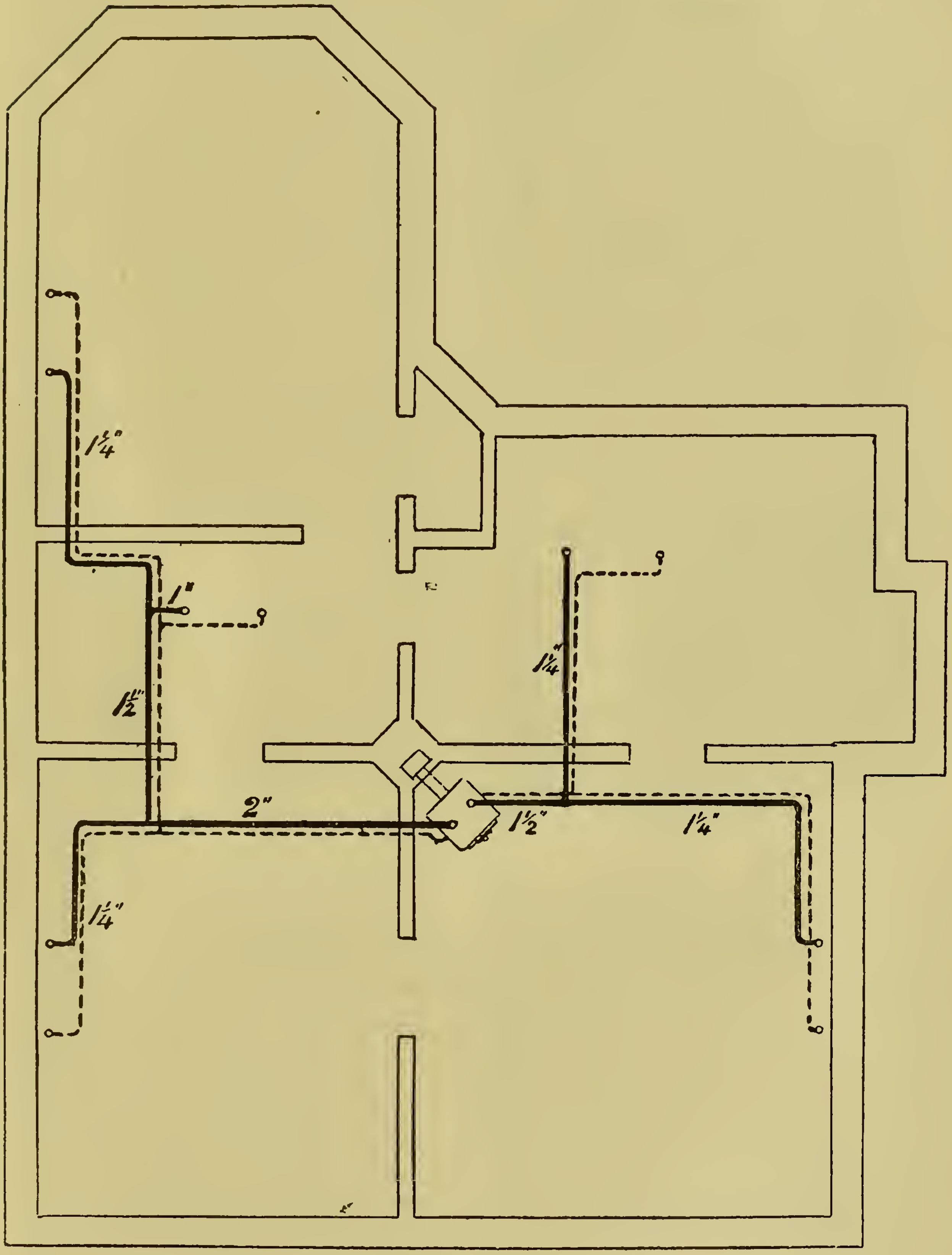
* These boxes can be made of wood, or lath, or wirework, cemented over and whitened with the ceiling below.

The object of this is to allow free escape of steam if the apparatus be over-heated, as may very likely happen in this case, the boiler probably being tended by a lad employed in the house. The over-heating would not be a source of danger even without the expansion pipe ; but if this did not exist the boiler would relieve itself by way of the cold supply pipe and flood the place.

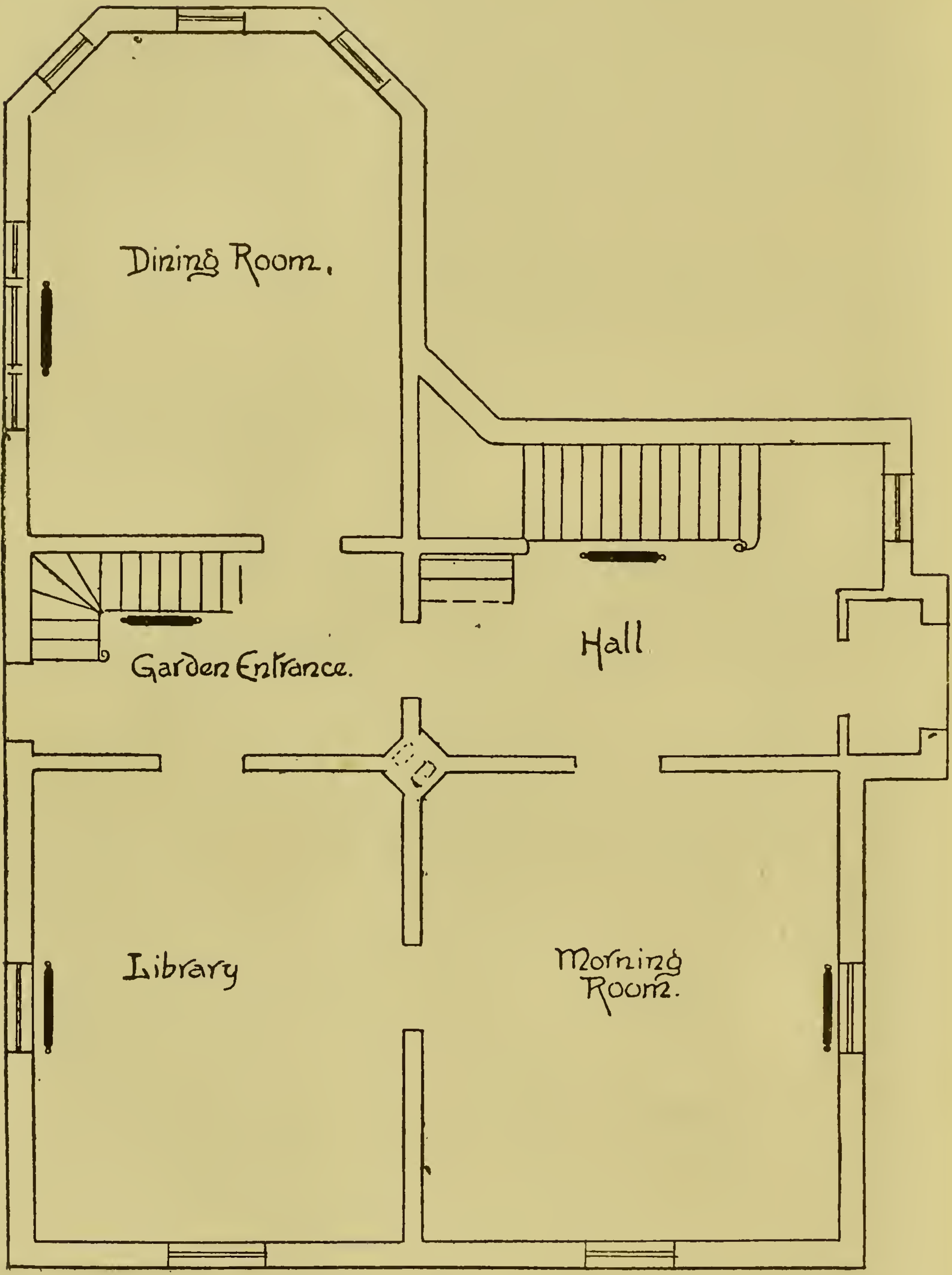
The pipes in this apparatus not extending a very great distance, as usual in a residence, might be 1½-inch for the short piece of flow just on top of the boiler to the junction shown a few inches above, 1¼-inch flows (and returns) from thence as far as they constitute mains, and the branches from the mains 1 inch.

Figs. 231 and 232 are the basement and ground floor plans respectively, of a rather large suburban residence, and this example is introduced to admit of several things being discussed. In the first place the average large suburban house is badly warmed as a rule, the builder merely providing a fireplace to each room, and these grates are rarely adequate in severe weather. In houses such as these the reception rooms are large, some of them commonly exceeding 20 feet one way, but even with a 16 feet × 16 feet room of good height, a grate has to be both large and effective to warm all parts. Even if it succeeds in doing this, it means that in the vicinity of the fire the heat is too great, otherwise a comfortable heat could not be experienced in those parts of the room remote from the fire. The general rule is for about one-half the room only to be ordinarily comfortable when the outside temperature is below freezing point, while the front and back entrance halls are exceedingly cold, and furnishing cold draughts to the rooms around ; and above, by way of the staircases. It is no exaggeration to say that a good-sized house of the kind is often positively disagreeable to live in during frosty weather. This is sought to be overcome by placing a stove in the front hall, and it does a deal of good, provided it is possible by a flue being there. If there is no flue, a flueless gas or oil stove is used, for although these



Basement Plan

Fig. 231.



Ground floor Plan.

Fig. 232.

appliances are sometimes unpleasant, something has to be done to raise the temperature.

This example apparatus is, therefore, introduced to show not only a perfect way of overcoming the trouble, but to illustrate what may be termed an auxiliary heating apparatus that should appear in houses of the kind in question. If the cost will admit, this arrangement will give a degree of comfort, healthful comfort, that cannot possibly be known in houses that rely on fire-grates or stoves only. It is supposed that fire-gates exist in all the rooms of this house, although this provision is not shown on the plans. If they exist, there is no occasion to dispense with them unless desired. They can be used in the very severe weather if the sight of a fire is wished for. At other times, say when the thermometer is above 30° F., they will not be in request either for appearance or warmth, moderate sized radiators being sufficient at other times. The retention of the fire-places (with open chimneys) fulfils all that is required in the way of ventilation, either when the fires are alight or when they are out. This plan becomes a highly successful mode of heating for residences, a combination of fire-grates and radiators being capable of meeting every one's sense of comfort.

In the illustrations the basement is shown containing the boiler and the whole of the pipes, while the ground floor shows the positions of the radiators. The radiators should be connected up with an angle valve one end, and an elbow at the other, and both these connections are best made with unions (see p. 282). The positions of the radiators may be varied. For a purpose like this, some engineers prefer to put them under the windows, while others choose a position as near the door as possible, so as to catch the incoming air. The writer favours the latter plan in residence works where there are active chimneys in each room. There certainly is a falling of cold air at windows, also an entrance of cold air around between the sashes and frames, but a still greater inflow of cool air will be experienced at the doorways, even if the doors are partially or quite closed.

Of course the air of the front and back entrance halls is warmed to some extent by the radiators there, but not to a comfortable degree, on account of its rapid movement. The air of these halls practically supplies the whole house ; consequently the warmth afforded by the radiators there is quickly carried away, some passing upstairs, some passing into the rooms around. The warmth from these two points is, in fact, felt in every part of the house, but it is not sufficient to make the other radiators unnecessary. The air of the halls may be said to have its chill taken off, and radiators placed just inside the doors complete the good work as the air passes in. Upstairs there may be no radiators at all, the warm air ascending from the halls usually being considered sufficient. Properly speaking, it should not be considered enough, and presently it will be better recognised that properly warmed sleeping apartments are more healthful. Every medical authority admits that the cold air of sleeping rooms during the early hours of winter mornings ought only to be borne with impunity by the most robust. With the aged and young to sleep in rooms where the water in the bowls probably shows ice on it, tends to cause illness directly or indirectly, and to lower vitality.

In the basement plan it has been assumed that the boiler comes centrally, consequently the arrangement of pipes is on the ordinary two-pipe principle. A flow and return is carried in different directions almost from a central point, the flow services as solid black lines, the returns as dotted lines. Had the boiler been away from the centre, this set of radiators might have been connected on the "one-pipe" principle with advantage. This latter system is explained in the next chapter.

The cold supply cistern might come under one of the staircases, and an expansion pipe could be continued from one of the 1¼-inch branches through the outer wall. The sizes of the pipes used are marked in the illustration, but as the radiators would probably be under 40-feet surface each, the valves and connections need only be 1 inch. 1¼-inch branches are shown leading to the radiators, though 1 inch would probably do. When the whole of the circulating pipes do not extend more than two or three feet above the boiler, it is best to use a tube of one size larger than usual. The circulation is not of the strongest in such a low-built apparatus.

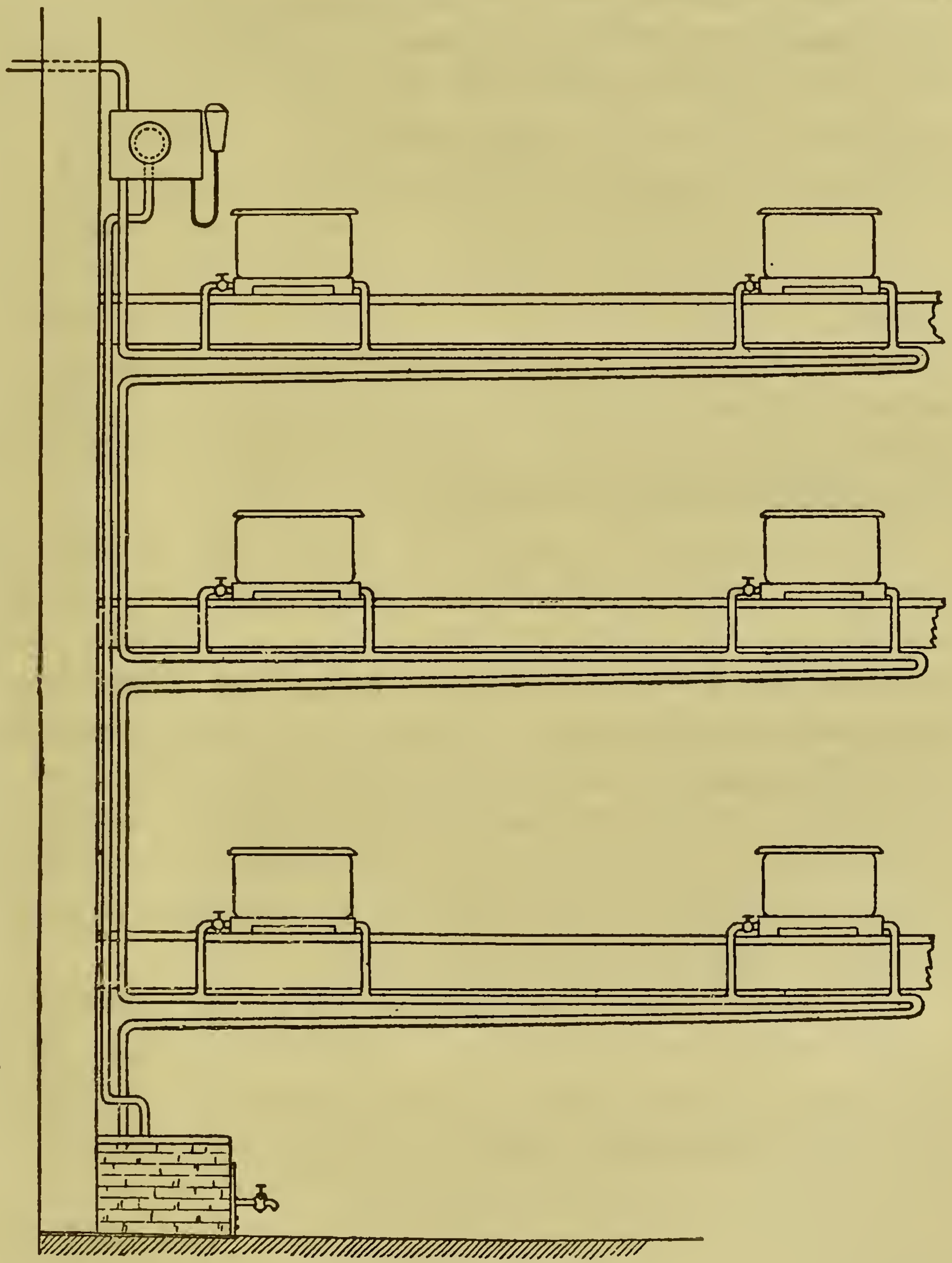


Fig. 233.

Fig. 233 represents an apparatus which we may suppose is devoted entirely to heating three landings, or short corridors, situated one above the other as shown. The chief object in showing this is to illustrate a plan that is very often adopted in works that extend some distance in height, viz. the connection of the radiating media wholly to the return of the mains. It is usually contended, and Hood bears out this contention, that if an apparatus like this was erected with all the coils connected to the flow, there would be a probability of the circulation starting up the wrong pipe from the boiler, owing to the much greater quantity of water there would be to move in an ascending direction (in the flow and its attachments) than there would be in the contrary way down the return. On this account the greater bulk of water would be expected to offer some extra resistance to the upward flow of water, and so cause the upward circulation to choose the passage that offered the freest way.

This argument is sound, but based very greatly upon theory. The chances are that this might have happened sometimes,* but certainly not if a good distance existed between the flow and return at the points where they are connected into the boiler. However, as a risk may sometimes exist, the argument may be believed in, especially as we can get quite as good, and almost as quick, results by utilising the return pipe. Therefore in an apparatus like this the principle should be adopted, as also in any other apparatus of a similar character, supposing it to be possible.

If circumstances permitted, a saving of pipe and improved results could be effected by running the return pipe as Fig. 234,† and, as a matter of course, we should, by decreasing the length of the pipe, cause the results, particularly with the lower radiators, to be much more quickly arrived at.

With this apparatus a tank is shown at the highest point, this being a very practical arrangement; it need not be large, say, 20 gallons, and the supply cistern at side arranged to fill it just a few inches up; this gives room for expansion, and prevents water being ejected if the apparatus over-heats. This tank may have a loose-fitting cover, or it can be a close tank with a good sized steam pipe carried from the top of it as shown, this pipe being turned into a roof, or better still, through an outer wall. Although not illustrated, an overflow pipe should be provided to the tank, this overflow being just below the level of the top of the supply cistern.

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* The writer has never tested this argument, as the return pipe acts well, and leaves little room for improvement.

† This apparatus is thus converted to one on the "overhead" system, as will be seen a few pages further on.

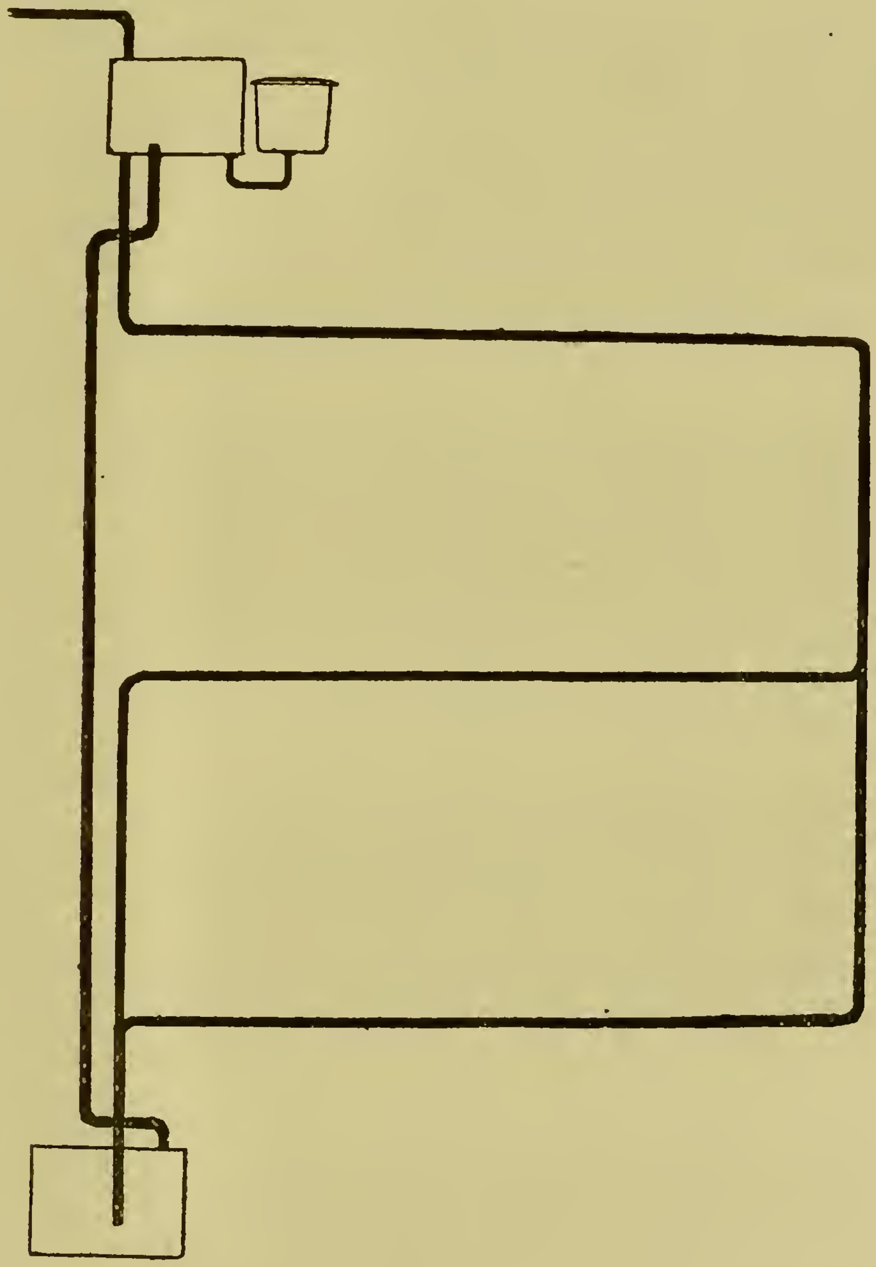

Fig. 234.

Each of the radiators in this apparatus should have a stop-valve. The sizes of these will be regulated by the sizes of the radiators, see p. 294. One cock will not entirely prevent the radiator getting warm after a time, but this is of no importance, as the cocks are only provided to check the circulation when the radiators may be giving off too much heat, or if it is found that the top radiators heat much more than the lower ones. None of the radiators would require to be shut off entirely, as it is to be supposed the fire would be let out if no heat whatever was required. Two cocks could, of course, be put to each radiator if required.

A very desirable plan in an apparatus of this size is to cover the mains, particularly the flow, which conveys all the heated water a good distance without its doing any work. If they are not covered there will be a great loss of heat, and there will be a proportionate decrease of heat at the points where it is wanted, and for the purpose that the apparatus is erected to fulfil. The fact of all coils being connected to the return makes it more than usually necessary for the mains to be protected, as the water, when it is hottest, has to travel a good distance before it can do any useful work. It is only at the radiating media that radiation should be permitted. An air vent would be needed upon each radiator at their highest points as usual.

The size of pipes might be 1½-inch for the mains,* or 1¼-inch would suffice if the corridors were but short, or with only one radiator each. For the coil connections 1 inch or ¾-inch, according to the size of the coil; the cold supply ¾-inch, with the usual dip; and the expansion pipe might be of the same sized tube as the flow pipe, turned down at the end to prevent dirt falling in. For the last mentioned reason also the supply cistern should have a lid.

In Fig. 235 we have an apparatus in which the return pipe cannot be utilised in the way laid down in the last example, as, in the first place, this undertaking is on too large a scale, and it is difficult to adopt this method when radiating pipe is used, as shown on three floors, instead of coils or radiators. This illustration is intended to represent four floors of business premises, heated from one boiler, and with one main flow and return only.*

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* These are merely suggested sizes. The sizes of mains are governed by two things—viz. whether they are horizontal or vertical, and secondly, the quantity of heating surface they serve. Tables giving these particulars will be found a few pages further on.

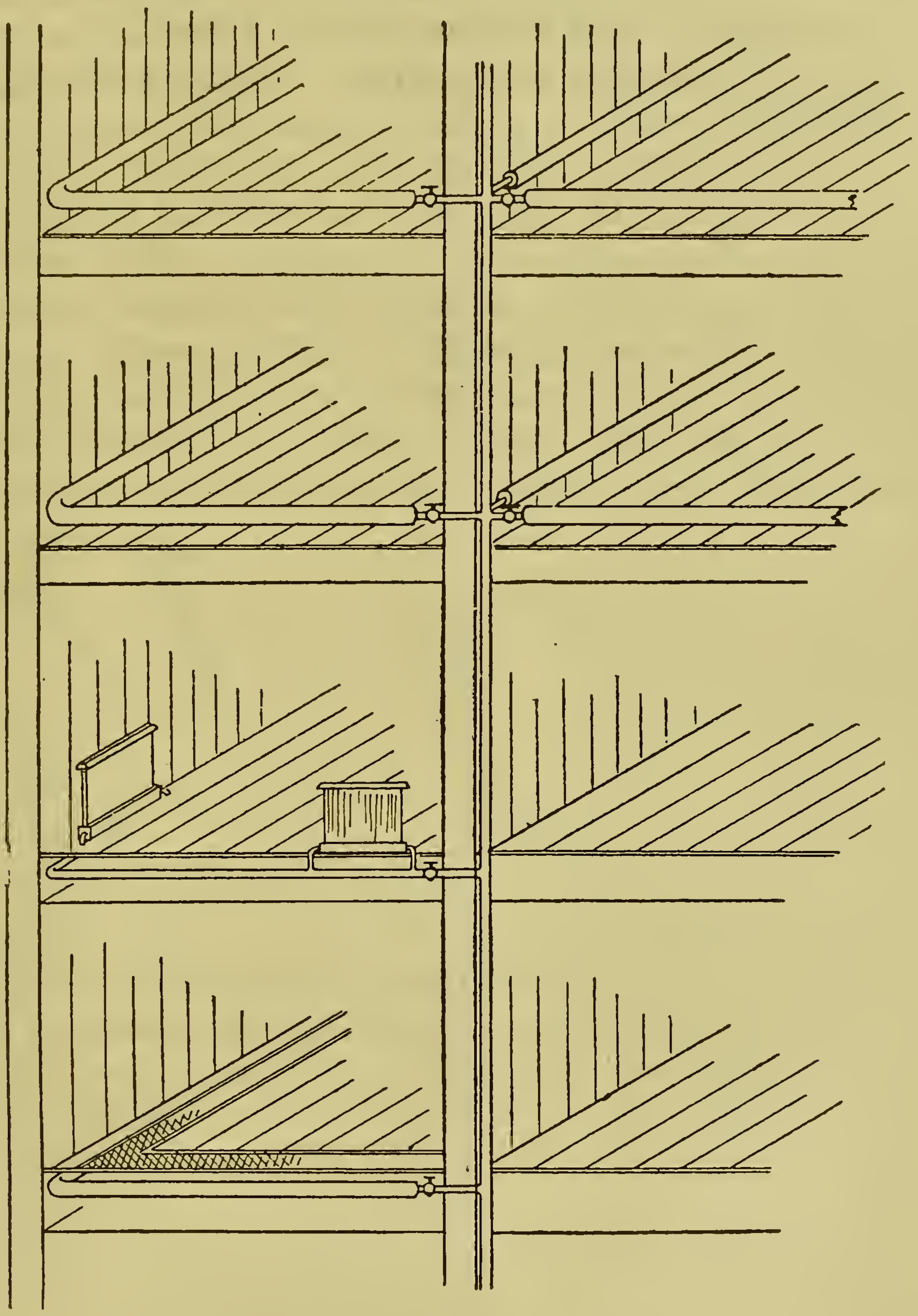

Fig. 235.

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* This illustration will only permit of the "flow" pipes being shown.

The recognised objection to this example is the vertical mains, for in these the circulation is very rapid, and inclined to pass by the horizontal connections, and not through them, This objection is well founded, but in a rather limited sense, as it only exists when the apparatus is being heated up, at which time it would be, perhaps, considerably longer before the radiating surfaces were fully hot, than it would be if some means existed for diverting or causing the first heated water to enter the horizontal services in question. When, however, the whole apparatus is once heated the objection is disposed of, and it may be concluded that it will not readily recur, as an apparatus on this scale would not have the fire put out except for mild and warm weather. Engineers, however, consider this feature a fault, and adopt different measures to overcome it. A common remedy is to use an elbow and T-piece in the flow at each branch service, as seen in Fig. 236, but this does not recommend itself on the score of convenience, or of sightly workmanship. Sometimes the connection is as Fig. 237, which will probably induce a circulation through the horizontal service more successfully than the other method. Equally good results, with a more workmanlike appearance, can be got by using the special fittings as described on p. 277. An even better fitting is to be had as Fig. 238 (section).*

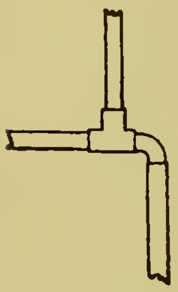

Fig. 236.

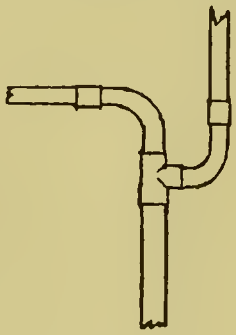

Fig. 237.

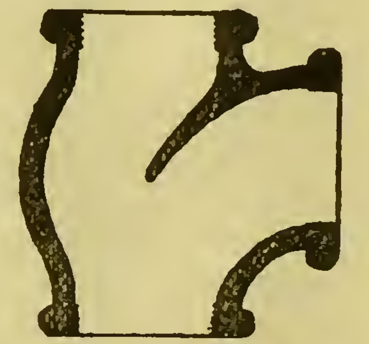

Fig. 238.

The illustration shows the lower floor heated by hot-water pipes ; 3-inch would probably be best, in a channel beneath the floor-level covered with a grating. This needs no further explanation except to point out that the usual extra allowance of pipe for trench work must be made. The grating just

* (Kinnell's patent.)

over the stop-cock should be easily removable, as the cock would be placed in the trench. If there is much foot traffic across the grating at any one point, and it is found slippery and unsafe, a mat could be placed over it just there. The whole of the gratings should be removable for cleaning the pipes, and the trench must not fit the pipes at all closely. All these latter points have been explained before.

On the next floor a set of radiators are supposed to be adopted, these being shown connected to the flow of the branch service.* In this case there is no objection to their being on the flow, although the results would be almost as good if connected to the return. A stop-cock would be needed in the flow, at about the point shown, with some easy means of using it, and a stop-cock might be fitted to each radiator if circumstances made it desirable.

The two top floors, which we may consider to be store or work rooms, are heated by plain pipes, 3-inch or 4-inch, exposed and carried round whichever way is most convenient to avoid doorways, &c. The flow of these pipes would be connected to the main flow, as on the two other floors, and returned into the main return; each branch flow having a stop-cock, somewhere close to where it is connected with the main, as shown. Each branch service of radiating pipes would require an air vent at its highest extremity, and each radiator would need an air cock as usual.

The sizes of main and branch pipes must be proportionate to the increased size of the apparatus. Accurate sizes will be found on page 345, the sizes depending upon the quantity of pipe and radiating surface. Suggested sizes for this example are 3-inch mains, which might be reduced to 2½-inch above the first floor and 2-inch above the second floor, 2-inch connections between the mains and radiating pipes on first floor; 1½-inch branch service to supply the radiators, but only 1-inch from this branch service into the radiators; 1½-inch connections between the mains and radiating pipes on the two top floors.

* On the " one-pipe " system explained a few pages further on.

It is very necessary to point out that it would be decidedly better if two distinct sets of mains could be carried up; this would give more regular, and quicker, results than the one set of mains, shown as an example upon the supposition that only one set was permissible. If two sets could not be conveniently carried in two directions, which is not absolutely necessary, they can be carried up together, the branches from one set taking one side of the building, and the other set the other side.

There is one well-known engineer in London who, whenever he can, carries a distinct flow and return from the boiler to each floor, and the practice ensures excellent results, but is not usually possible for various reasons, such as cost, the appearance of the stack of pipes,* &c. No one, however, could find fault with the way in which the apparatus would work.

If the mains are doubled or trebled in number, they need not be so large, the size decreasing with the increase in quantity. These sizes are given in the tables, p. 345, but it must be borne in mind that they may require variation under varied circumstances, such as the introducing of large hot water pipes instead of radiators, &c.

Sometimes one main return can be made to do duty for two flows, or even for three if the return be of a little larger pipe, and there is no objection to this. Neither would there be any drawback to one flow serving two returns if the radiators are wholly connected to the latter.† One 2-inch pipe would readily serve two pipes of the same size, as at all times the circulation is very rapid, this being the reason that the connections between mains and radiating pipe may be small, as already mentioned.

All non-radiating surfaces should be covered with some poor heat-conducting material.

In dealing with churches, chapels, lecture-rooms and public halls, we have commonly to consider some of the features that exist in horticultural works, chiefly that of low motive power. In nearly all the works mentioned small main and connecting pipes are generally prohibited. If a church, there will probably be one set of 4-inch or two of 3-inch mains from the boiler to the trench pipes, or if the heat is distributed by stacks of pipes, coils, or radiators, the mains will then probably require to be 3-inch, unless the place be of quite small size.*

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* The pipes would be smaller proportionately with the increased number.

† See the "Overhead system," in the next chapter.

In these works a result usually sought to be attained is the quick heating of the place, that is, in the shortest possible space of time after the fire is lighted, as it is not usual to keep the fires going day after day† when the place is not in use. Consequently, it has become customary to arrange for warmth to be quickly supplied, almost at any moment, or at least in a few hours after the fire is lighted. This end is arrived at by using smaller radiating pipes (in proportionately larger quantity). It will be seen that although two 2-inch pipes have fully the same radiating surface as one 4-inch, they do not hold so much water, and the less the bulk of water the quicker it becomes heated, if we suppose a boiler of equal size to be used in each case. It might be profitable for some one to introduce a pipe of special shape for this work, having a greater radiating surface in proportion to its contents, but much judgment would be required to secure success, as too small a quantity of water would cool (i.e. lose its heat) before it had completed its circuit, and it would not do to have some part of the return pipe cold. The pipe could be of a shape that would not readily collect dust.

It is not intended to suggest that all such works are carried out in small pipes, but only those in which a particular wish has been expressed for rapid results. For instance, in a public hall or lecture room only used at irregular periods. The majority of church works on a good scale have 3-inch or 4-inch pipes in trenches, and the fires are sometimes lighted the day before the place is required for use, unless the fires are kept alight perpetually as is necesssary when services are held daily or three or four days a week.

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* This is an instance where a table giving sizes of mains for a given radiating surface is likely to err. The whole apparatus does not extend more than four or five feet above the boiler, and the radiating surface is in many cases wholly large pipes holding a large bulk of water. Larger mains are thus needed.

† Many churches are an exception to this, as services are held almost daily.

The major portion of church work is carried out in trenches, as exposed pipes cannot always be tolerated. Radiators for church work are now being used to a considerable extent, but the arrangement of the pews and seats makes this difficult in existing buildings. Trench work, however, is not always practicable, as it is occasionally difficult to get the boiler low enough. In such a case the flow pipes are carried along the walls of the building and the returns brought back down the centre in a trench. In heating an old church, however, another difficulty may present itself in the fact that vaults may exist along the aisles; in such a case exposed pipes or radiators, or coils beneath the floor at certain points, have to be resorted to. It must not be forgotten that, although we obtain heat more quickly with small pipes, or any pipes holding a small quantity of water, we shall just as quickly lose the heat as the fire goes down.

Sometimes it is more convenient to adopt a combination of two or more methods, say trenched pipes and coils or radiators, as although in many cases the former of the two is perhaps best for the body of the building, it would be very desirable to place a coil or coils in the entrance lobby or way, or wherever the cold air may be found to have free ingress and cause draughts. Coils or radiators will generally be found best for cloak or ante-rooms, vestries, &c.

Suggested methods for carrying hot water pipes either in continuous runs or in mains and branches, have been shown, and also the connecting up of a series of radiators or coils; if, however, it be desired to connect up three parallel rows of pipes in trenches, it can be carried out as Fig. 239. This shows the mains with a fairly good rise up to the further branch—a very desirable arrangement where possible. It must also be remembered that the branches in the trenches must have the customary rise to the furthest extremities, as fully explained with glasshouse work, and all the needful precautions as to expansion, joints, &c. &c., require consideration, as have also been fully treated. The apparatus just suggested should have an expansion pipe from the boiler or main flow, the services having air cocks, not air pipes. The supply cistern, of a sufficient size, must be placed in some convenient spot a little higher than the highest point of the radiating pipes (or coils) and connected into a return pipe; the main return would probably be convenient for this. There would be no need for stop-cocks or valves, unless some special circumstance had to be considered.

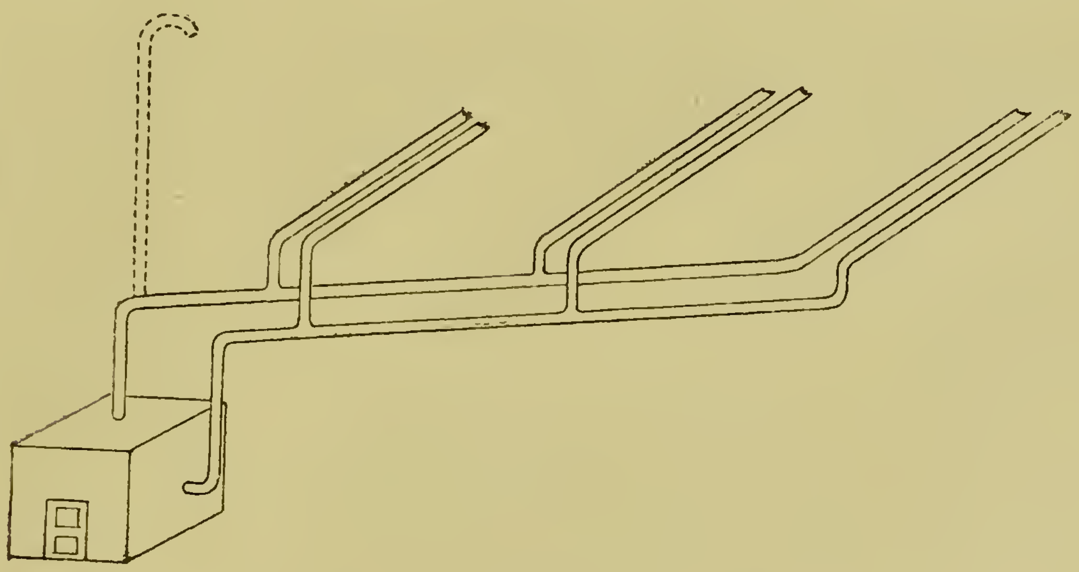

Fig. 239.

As just mentioned, it is sometimes impossible to lay the pipes in trenches in church work owing to the existence of vaults, &c., and if exposed pipes along the wall were considered particularly objectionable, it could be arranged for stacks of pipes, laid flatways, to be placed in shallow pits here and there, if there was a possible way of carrying the connecting pipes from one to another. These pits would probably have to be put in the aisles, but even there they are unpleasant in effect, as the seats near them receive a more than comfortable share of heat. They are covered with gratings, and act in the same way as coils placed beneath a floor, p. 322, and may have fresh air conducted to them if desired. In any case the pipes must be calculated at a less heat-giving value than those that are exposed ; about the same allowance as for pipes in trenches has to be made.

CHAPTER XIX.

EXAMPLES OF LOW PRESSURE APPARATUS.

THE LATEST PRINCIPLES.

The newest details of the Two-Pipe system—Proportioning sizes of mains and branches—Sizes of radiator connections—The One-Pipe system, its application and advantages—The Overhead system, its application and advantages—A One-Pipe system with graduated duplicate mains—Working any of these systems under a light pressure, advantages and faults.

THE examples about to follow are made the subject of a separate chapter, as they are of a more advanced character than those already given. In the previous chapter there are new details given which have not appeared in previous editions, but in this chapter the information is wholly new, and the latest that is known at this date. It is largely made up of particulars and practices that were practically unknown in England quite a short time ago.

Briefly, the information to be given will consist first of some details connected with the old style of two-pipe system—such as the proportionate sizes of mains, sub-mains, branches and radiator connections. There is more known in regard to these details than was the case a few years ago, and they go far to insure good and equal results.

Secondly, a description of the one-pipe, or simple circuit system—a system that has no equal for horizontal works where the whole of the radiators are on one or two floors, and the floors are of large extent. These conditions apply to most banks, restaurants, lecture-halls, some hospitals, and similar institutions and places. The last apparatus erected on this system by the writer is in Lloyd's Bank, Ltd., Law Courts Branch. There are 70 radiators, and no other system could be relied on to give such regular results from the first trial as this has. Regular and equal working is one advantage of this system; while another is the reduction in the quantity of pipe required. It is undoubtedly the most simple form of apparatus yet known.

Third, the "overhead" system, by which the mains in the basement are reduced in number and almost entirely done away with. This system is well adapted for the large type of city buildings that are let out in offices. It is quite recognised now that the basements of such buildings can be fitted and let as business offices, and realise a higher rent than some of the floors above. In fact, for general convenience, the basement is only excelled by the ground and first floors, even in buildings fitted with lifts. Under these circumstances it is highly desirable that no network of mains or other pipes exist throughout the basement floor, and the "overhead" system is the best in effecting this.

Also an arrangement that might be styled "the graduated duplicate-main one-pipe system." This plan gives very good results when there are a number of vertical sub-mains carried up in the different angles of a building, all fed from horizontal mains in the basement. There is total immunity from short-circuit, and the most equal results possible are obtained. It is a plan whereby the water of the furthest sub-main (presumably the coolest water) is the first to return into the boiler, and the water of the first sub-main is the last to return there. The graduation in the sizes of the mains—the flow decreasing and the return increasing—allows every branch main to have an equal share of the hot water, and be properly relieved of that which is cooled.

Added to these distinctly different systems of apparatus there are combinations of one with the other, as can be very easily arranged; and there are combination heating works in which warm air is utilised for the ground floors, and direct heating radiators for the more remote rooms. These latter will be found in the chapter devoted to warming buildings by heated air.

For very large apartment buildings there have recently been instances of the heated water to radiators being circulated by the aid of a pump. This entails the installation of an engine-pump and its subsequent maintenance; but it admits of the apparatus being carried out with pipes of a little smaller size, less in quantity and an almost total disregard of rise and fall, which is so necessary for a convective circulation. This system needs no other explanation, as no important or peculiar principles are involved.

THE TWO-PIPE SYSTEM.*

Fig. 240 illustrates what may be termed a typical example of the old two-pipe system, the system that is most largely practised for general purposes; but not having the advantages of other plans under certain conditions. In this, all connections are flow and return, whether they be mains or branches, and the result is that the hot water proceeds direct to its work, and then immediately returns to the boiler. Taking the sub-main, marked S M in the illustration, for example, a

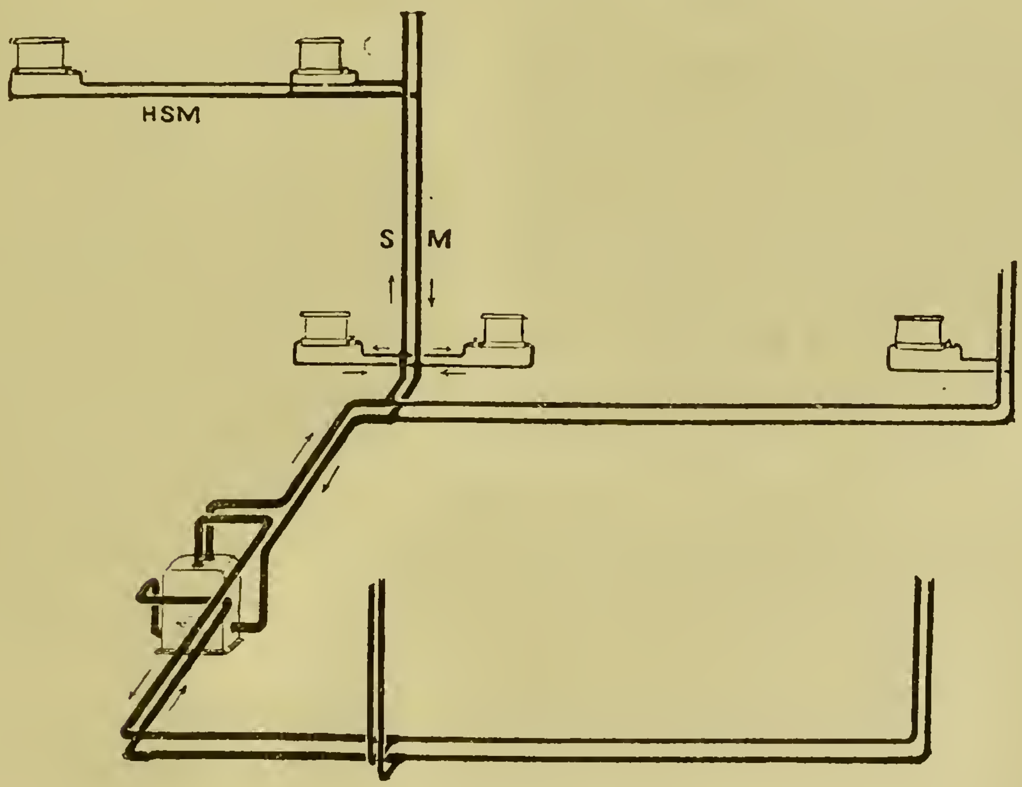

Fig. 240.

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* This system has been dealt with in the last chapter, but without the advanced details given here.

proportion of the heated water passes up this flow pipe, and after passing through the radiators joins the main return as shown. It then proceeds direct back to the boiler to receive more heat and circulate out again.

On this account there is no reason for carrying a main service in its largest size for the whole of its length, and it may be reduced as it passes each branch. The reduction must bear a fixed relation to the amount of work disposed of, and the amount of work yet to be done. It is the same with the sub-mains and branches: these start with a pipe that is known to be of a full size for the total work to be done; but there is no occasion to continue with this size pipe after passing some of the work.

In recognition of this, a table of sizes for pipes, whether for the largest mains or the smallest branches, becomes an important feature in calculating for this work. Such a table is largely based on the radiating surface the apparatus has to keep hot, as radiators are (or should be) now made to recognised proportions—that is, to hold a quantity of water in ratio with their surface.* A table based on heating surface alone, however, leaves much to be guessed, and the better plan is to have tables giving sizes of branches to serve certain areas of radiating surfaces, and then to have a table giving the sizes of mains to feed a certain number of branches of various sizes. The following tables are based on the radiating surface, being radiators, and not hot water pipes. The latter, particularly the 3-inch and 4-inch sizes, hold such a much larger quantity of water for a given surface, that the results are varied to some extent.

In this table it is understood that every branch to a single radiator is of the same size pipe as the radiator connection. In other words, if a radiator has, say, 40 feet of surface, it will be tapped for 1-inch pipe, and the branch serving it will be 1-inch pipe throughout, both flow and return. The stop-valve and union will be 1 inch, with a clear way through. If any branch goes to serve two or more radiators, then the next table must be consulted as it becomes, for purposes of calculation, a main. Such a branch is marked H S M on the illustration. The first radiator on this horizontal service has branch connections of the size given in the following table, and so has the second, for the last radiator on such a service is treated as being connected out of a main. It will be seen that part of the service is of larger pipe—viz. that part which has two radiators to serve—

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* The table, therefore, is not applicable if ordinary hot water pipes are used instead of radiators. See Radiators.

SIZES OF RADIATOR CONNECTIONS AND RADIATOR BRANCHES, FOR ANY SYSTEM OF APPARATUS.

Surface of Radiator.	Size of Radiator Connections, Service Pipes and Stop-cock.
Up to 16 ft.	¾ inch.
16 ft. to 48 ft.	1 ,,
48 ft. to 100 ft.	1¼ ,,
100 ft. to 150 ft.	1½ ,,

This table, like all those connected with hot water works, will bear variation under special conditions. If a branch to a single radiator extends an unusual distance, say over 30 feet horizontally, it will be well to give it a size larger pipe, though the cock and connections at the radiator need be no larger. The object of the larger pipe is to get the heated water to the radiator more quickly, and it might not be needed if the flow pipe was carefully covered to prevent loss of heat. These sizes may be considered to apply to the ground and first floors of a building; higher floors can have radiators with 15 to 20 per cent. more surface with the sizes of branches given :—

SIZES OF MAIN SERVICES.

Main.		Branches.	Main.		Branches.
1 in.	will serve	two ¾ in.	2½ in.	will serve	three to four 1½ in., or equivalent of smaller sizes.
1¼ in.	,,	three 1 in.			
1¼ in.	,,	five ¾ in.			
1½ in.	,,	three 1¼ in.	3 in.	,,	one 2½ in. and one 2 in.
1½ in.	,,	four to five 1 in.	3 in.	,,	three 2 in. (barely), or equivalent.
2 in.	,,	three 1½ in.			
2 in.	,,	four to five 1¼ in., or equivalent of 1 in.	4 in.	,,	two 3 in. and one 2½ in.
			4 in.	,,	four 2½ in.
2½ in.	,,	two 2 in.	4 in.	,,	six to eight 2 in.

This table will also admit of judgment being used in accordance with the conditions. If there is doubt, it is decidedly best to err on the side of putting one size larger pipe, not smaller. The sizes given, though, are for horizontal mains. When they are vertical, a little more work can be put to a given size of pipe.

With a table in which the sizes of all pipes are arrived at by the radiating surface to be dealt with, the figures run :—

Total Radiating Surface.	Size of Horizontal Mains.
Up to 100 ft.	1¼ inch.
,, 250 ft.	1½ ,,
,, 500 ft.	2 ,,
,, 850 ft.	2½ ,,
,, 1200 ft.	3 ,,
,, 2200 ft.	4 ,,

This table does not agree exactly with the previous one ; but allowance has to be made for the previous one not being likely to have the utmost radiating surface on all its branches. With this table also a little more surface can be added to a given size of pipe if the mains are vertical.

THE ONE-PIPE OR SIMPLE CIRCUIT SYSTEM.

As previously stated, this system of apparatus is specially well adapted for works in which there are but one or two (or possibly three) floors to be heated, these floors being of considerable area, and requiring radiators to be scattered about to afford an equable temperature ; or it may be that the floor is divided into a number of offices or apartments, and radiators are required in each. Under these conditions the system gives the best possible results, as all radiators heat satisfactorily ; the water in the first and last one on any circuit not differing in temperature more than about 15°. There is no risk of short-circuit, and every radiator must heat.

There is one thing, however, to be considered, and that is the disposal of the horizontal mains which come beneath the radiators. If the floors are concrete, then the mains have to run along the ceilings beneath, and should this floor beneath be an important one, the appearance of the mains and connections may be objectionable. A casing would hide them; but with good ceilings casings may be equally objectionable, and if this is so, the system becomes either impossible, or has to be modified to a large extent. Should the floors be concrete, with a wood flooring above, then space can generally be found for the pipes, although the apparatus should be well tested before the flooring is completed or closed again.

In the heating of a large bank (carried out by the writer) the ground-floor was devoted to the clerks and offices generally, and the mains run along the ceiling of a crypt beneath. The crypt, which was devoted to safe-deposit purposes, had a basement below it where the boiler was situated. This lowest basement had the mains along the ceiling for the radiators on the crypt floor, but it was not absolutely necessary that the mains for the bank floor be run along the crypt ceiling. Between the crypt ceiling and the floor above there was space enough for a man to crawl about; but it was the architect's wish that the pipes be carried in sight below. It is certainly desirable to carry pipes—when the length and quantity is considerable—so that they are always visible, for, with the best work, leakages will occur. The leaks that may show themselves at first testing are, of course, remedied there and then; but small leaks may develop themselves for possibly a month afterwards—not as a rule, perhaps, but it certainly does happen so occasionally. If a large apparatus is finished and tested in the summer-time, a leak or two may reasonably be expected when the apparatus is set to regular work later in the year. Leaks do not occur perpetually, however, after the system has once been overheated and subject to the trials that a new apparatus is liable to, with probably an unskilled attendant at the boiler.

Fig. 241 explains this system of apparatus, and it will be noticed that the radiators are wholly connected from, and to, one main pipe. There was a time that such an arrangement would have been considered impracticable as to efficiency.

In practice, though, nothing could work better, and the circulation of the water is most interesting and peculiar when observed in a model apparatus of glass tubes. It can be seen how each radiator takes a moderate share of the hot water, the bulk passing steadily along the horizontal main beneath. The fact of the water which leaves a radiator going into the main to serve another radiator is no fault, for each radiator reduces the temperature but very little. It can be noticed, too, that the water, which has lost a perceptible amount of its heat, does not pass into the radiators like the hottest water. By placing the hand first on the upper side, then on the lower side, of the main near where it returns to the boiler, a difference in temperature can be discovered. On this account it is best to connect from the top of the main always. If the radiator lies a little out of the path of the main, the connections should be as Fig. 242, and this mode of connecting should always be practised, in any system of hot-water works, if the mains are long and straight. The lengthening and contracting of mains must always be allowed for; but expansion slip-joints are seldom necessary if this method of connecting is adopted. The connections spring and allow for the push and pull of expansion and contraction. This is an opportunity to mention that when high straight vertical mains are connected

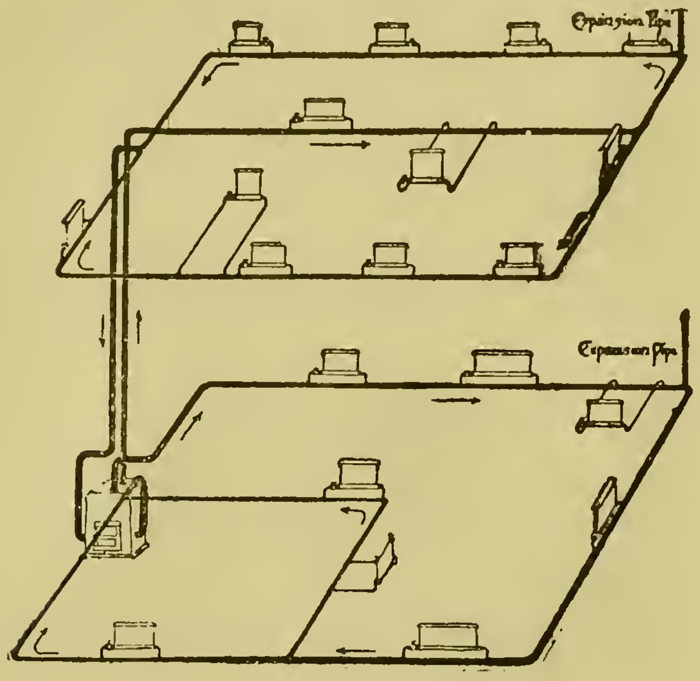

Fig. 241.

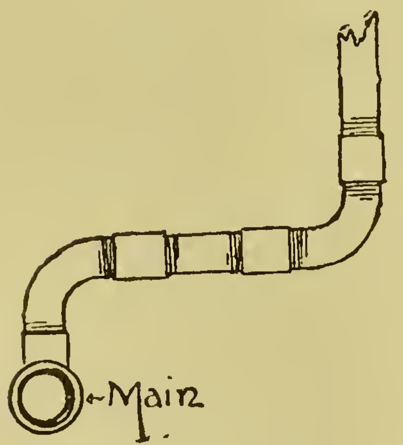

Fig. 242.

from horizontal pipes below, the connection should be as shown, to allow for extension of the vertical pipes.

Although this form of apparatus is styled the "one-pipe" system, it will be seen that the water flows up to the highest point of the circuit, and returns from there to the boiler, the same as with works erected on other principles. The difference, however, is that the connections are all made to one pipe, and this pipe does useful direct work along its whole length. In other systems one half the pipe does no direct work, only performing the office of a relief or drain-pipe to carry water back to the boiler when done with. The fault of this latter is that it carries water back which has a temperature practically the same as that in the flow pipe, and amply hot enough to do more service before returning to be reheated. With the one pipe the utmost utility is obtained from the water, and by skilled arrangement about one-third of the pipe is usually saved as against any other system.

Short-circuit is also impossible, as water cannot return into the boiler until it has done the full work required of it. With the older two-pipe system it is such a common occurrence for the circulation to proceed short of some branch, so that, although a certain proportion of the apparatus works successfully, some part of it fails, owing to the water in that part remaining quite or nearly still.

There are, however, precautions to be observed which are peculiar to this style of apparatus, and one is that the length of main which is the true flow pipe must not have more radiating surface (nor greater bulk of water) on it than the length of pipe which acts as the return ; in fact, it is a recognised rule in all hot water heating works that the pipe, radiating surface, or quantity of water should never be greater on the flow service than on the return. The flow pipe is that which leaves the top of the boiler and gradually ascends to the highest point of the circulation. From this highest point, wherever it may be situated, the pipe continuing back to the boiler is a return service. If there are branch mains, as shown in the apparatus, Fig. 241, then they must be returns—

i.e. descending services. The expansion pipes on the mains indicate the highest point of circulation, where the flows end and the returns begin.

Another feature peculiar to this system is that the mains cannot be graduated or reduced as the radiators are passed. They must be of equal size from beginning to end, as they constitute flow and return services in the one pipe, by conveying the hot water to the radiators and the cooler water to the boiler. Branches can be of less size, according to the radiating surface they serve, and if a main is branched and returns into the same main then neither branch need be as large as the single main, but can be proportionate.

To the best of the writer's belief, no table giving sizes of mains has been compiled for this system of apparatus. The sizes, however, are nearly the same as with the two-pipe apparatus last explained, except that whatever size the main starts with has to be continued its whole length, as just explained. This, of course, is an increase in cost for any single service, compared with the two-pipe apparatus, but is more than saved (usually) by the less quantity of pipe used.

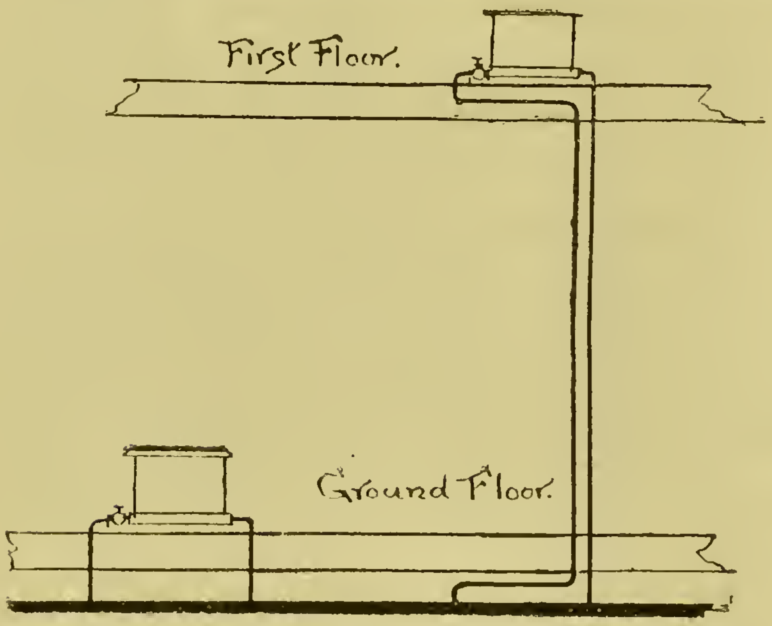

Fig. 243.

SIZES OF MAINS OF THE ONE-PIPE SYSTEM, MAINS RUNNING HORIZONTALLY.

Size of Main.		Radiating Surface.
1¼ in.	will supply	100 ft.
1½ in.	”	200 ft.
2 in.	”	450 ft.
2½ in.	”	700 ft.
3 in.	”	1000 ft.
3½ in.	”	1400 ft.
4 in.	”	1850 ft.

The radiating surface is supposed to consist of radiators, not large pipes. It is also assumed that the mains are not carried an unusual distance to reach the work. An average length of main would be 100 feet run to supply 100 feet of radiating surface.

The radiator connections are of the same size with this apparatus as any other, and in a complete apparatus each radiator would have a stop-valve in the usual way. If just two or three radiators are on a floor above the general work, it is not necessary to run a separate main to those if they can be connected as Fig. 243, which acts quite successfully.

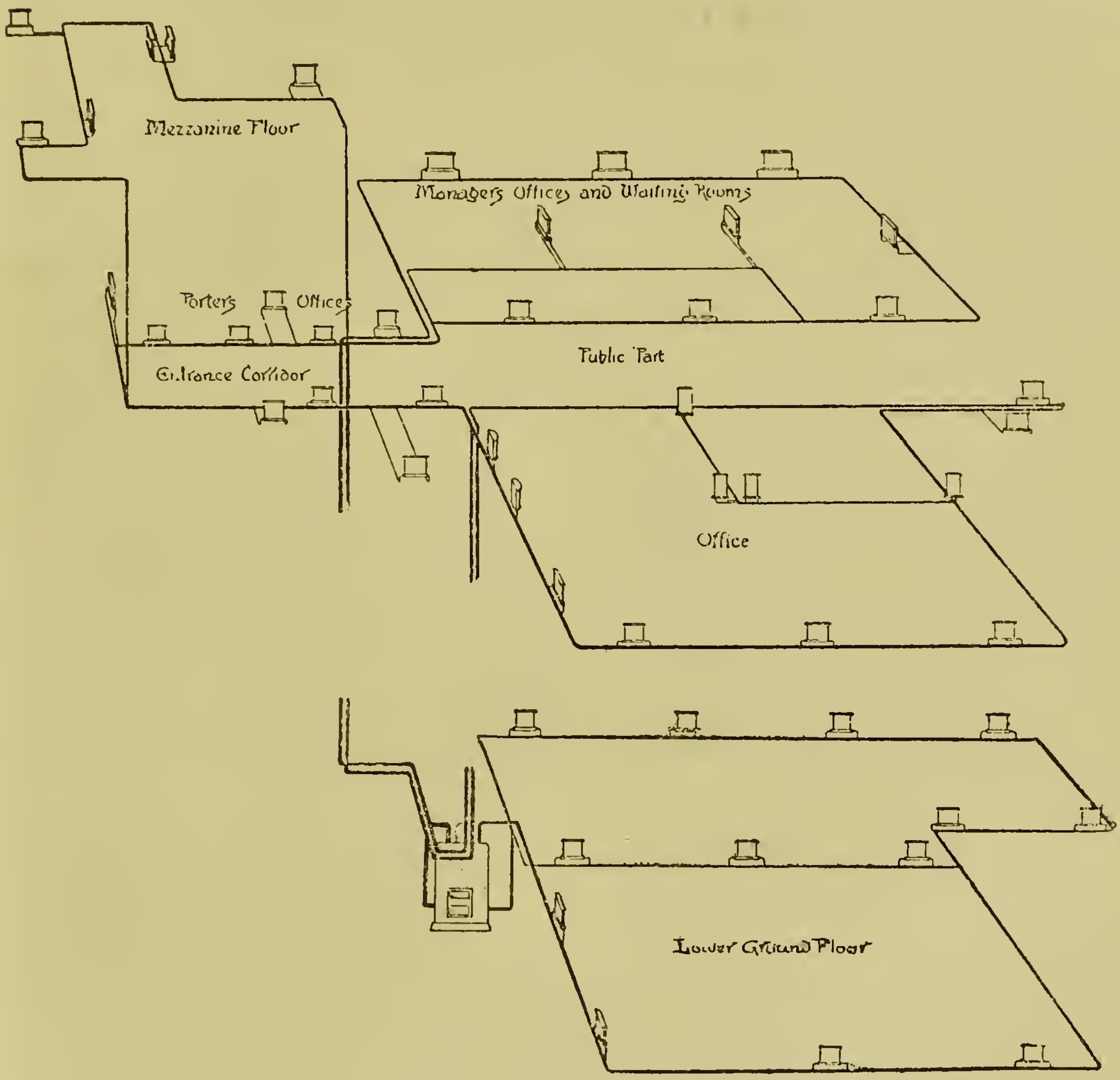

Fig. 244.

If more than one set of mains extend from the boiler, it is desirable to have stop-valves in each to control the circulation in any direction. One main service may have to go a shorter journey, and perhaps have more vertical pipe in it. This will result in a quicker circulation, and probably prejudice the other services if not checked. If a dead-shutting stop-valve is placed near the flow and return connections of each main, and an emptying cock inserted, it becomes possible to empty any separate main (in case of repairs, &c.) without extinguishing the fire or interfering with the constant working of the other parts.

In Fig. 244 is another example of an apparatus on the one-pipe system. This represents work planned and carried out by the writer, and is introduced partly because it has proved so successful in use. It will be admitted that illustrations of actual and effective work are preferable to showing works that are efforts of the imagination only. The description already given of this system of apparatus applies to this example, and further explanation is therefore unnecessary. The work extends from the base in which the boiler and lowest set of mains are, to a mezzanine floor situated above the entrance corridor leading into the chief office floor. It is not usual for the one-pipe system to extend to three floors above the boiler without modification, but in this case the conditions were favourable.

In Figs. 245 and 246 is a final example of the one-pipe system as adapted to residence work. As before mentioned the majority of people are content if the ground floor is properly warmed, leaving the bedroom floors either cold or to be warmed by fires when occasion demands. Certainly if there is a full sufficiency of radiating surface in the entrance halls, where the staircases start from, much will be done towards making the upper floors comfortable. If, however, radiators are required upstairs, then assuming it is only one floor above, they can be connected as Fig. 243. There might be one in the bath-room to advantage, also in a children's sleeping room.

This example also needs but little explanation after that which has been just given. The boiler is supposed to be in the basement beneath the dining-room, a single circuit running from that point around the basement ceiling and back again, as shown. From this pipe the radiator branches are taken out and into the one pipe as previously described. In this case it is supposed that the ordinary fire-places either do not exist or will not be used, even in the coldest weather. On this account there are two radiators shown in each room and in the entrance hall.

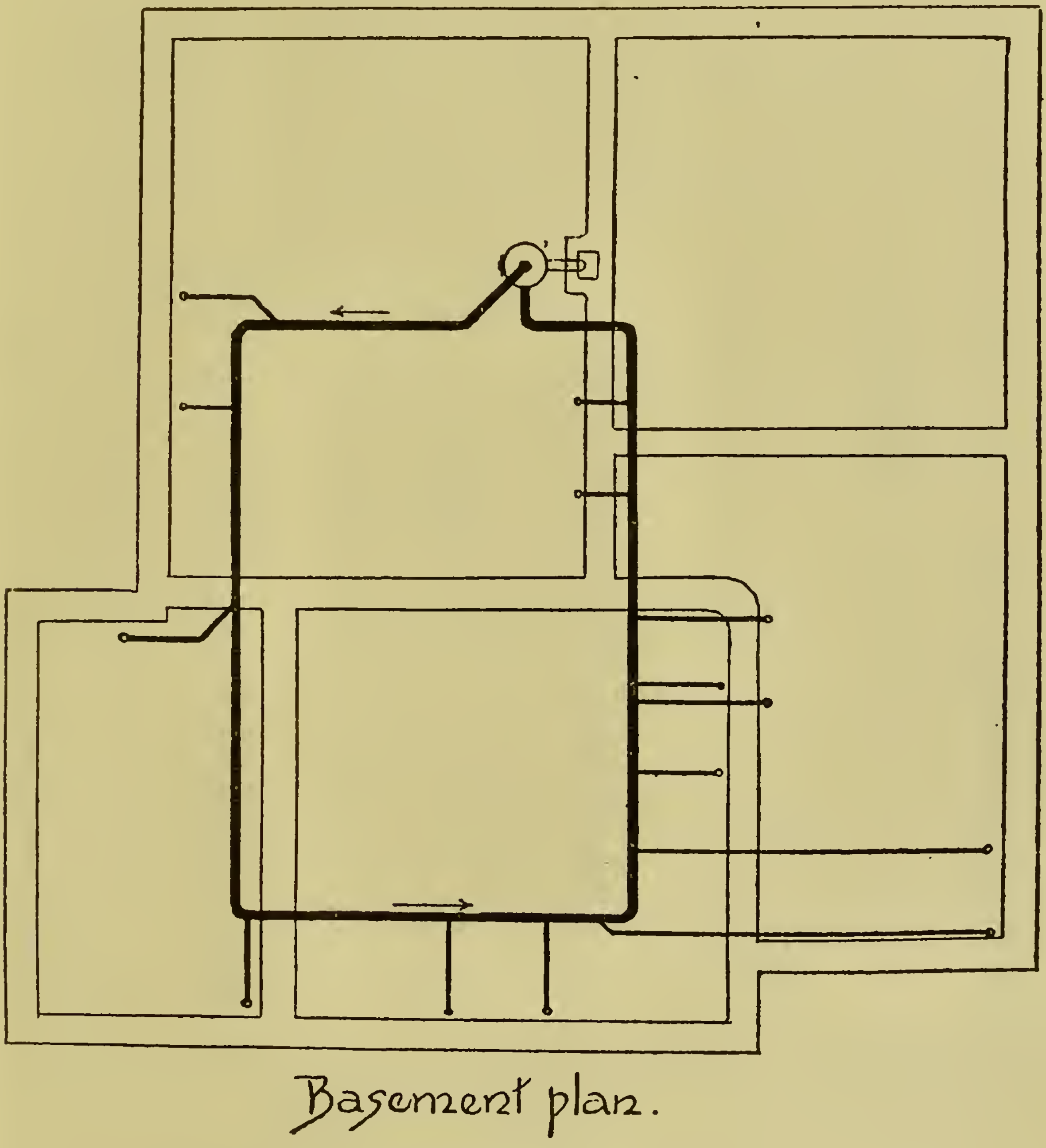

Fig. 245.

The practice of putting two radiators in a room, which could be heated by one larger one, has much to commend it. More equable results are obtained, and the radiators are smaller. The extra cost is very trifling as the radiators themselves cost no more. Radiators are now usually priced

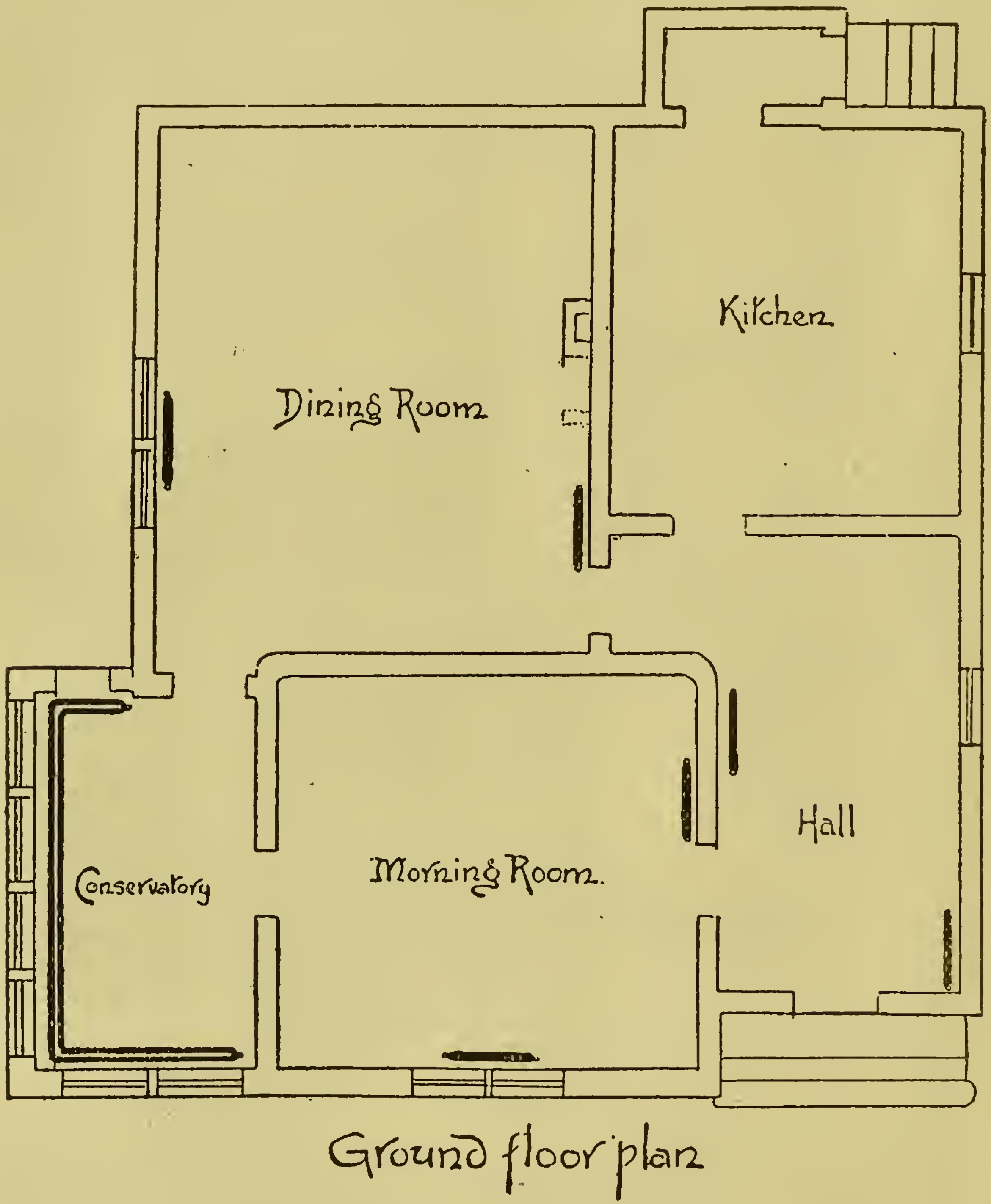

Fig. 246.

by the section or by foot of surface, so that one of 60 feet size is the same price as three of 20 feet or two of 30 feet surface, or *vice versâ*. The extra cost in using two raditors, in place of one of double the size, is in the extra stop-valve, air cock and pipe connections. The conservatory is heated by 2-inch cast pipes.

THE OVERHEAD SYSTEM.

This style of apparatus owes its name to the horizontal mains being carried on the top floor of the building, instead of in the basement as with other systems. In consequence of this, all vertical branches may be said to descend instead of ascend, as they usually do, and the water pursues a descending course in all of them.

Those who advocate and practise this system under all possible conditions contend that it has an important advantage in being so regular and uniform in its work—more so than any other system can always ensure. This contention will bear modifying, although when the conditions are favourable, it is a form of apparatus that can be strongly recommended for those very reasons. Where its adoption is particularly favourable is in buildings devoted to offices, and in which we may suppose the basement is a valuable space. In such cases the value of the basement is prejudiced if there are several sets of main pipes carried about the ceiling, and the overhead system of apparatus obviates this.

Fig. 247 illustrates this style of apparatus, and the peculiarity of the arrangement is that the flow pipe has no radiators or branches connected to it, but runs by the most direct route possible to a point higher than the highest radiators to be heated. If the apparatus is at all extensive, then the flow pipe may have to be of good size—that is, sufficient to furnish the hot water needed by the whole of the returns. If desired, there may be two or more flow pipes, as the system does not make a single flow pipe necessary under all conditions. It would depend on the form of the building.

Only one flow pipe is shown in Fig. 247, and it is supposed that this extends away from the boiler to the attic floor, as radiators are required on all floors below this. Radiators can be put on this floor as well, if desired. As soon as the flow service reaches the highest point, it is terminated with an expansion pipe in the usual way and as shown. From the flow pipe at the top is carried the horizontal service (or services), and as they commence to descend immediately they leave the flow pipe, they constitute return pipes from that point all the way to the boiler. From the flow pipe to the point where the return is branched and distributes its work, the pipe would be of the same size as the flow, but directly it is branched the different branches may be of smaller size. In other words, the sizes of the pipes should be proportioned to the work they have to do, much the same as with the older two-pipe system already explained.

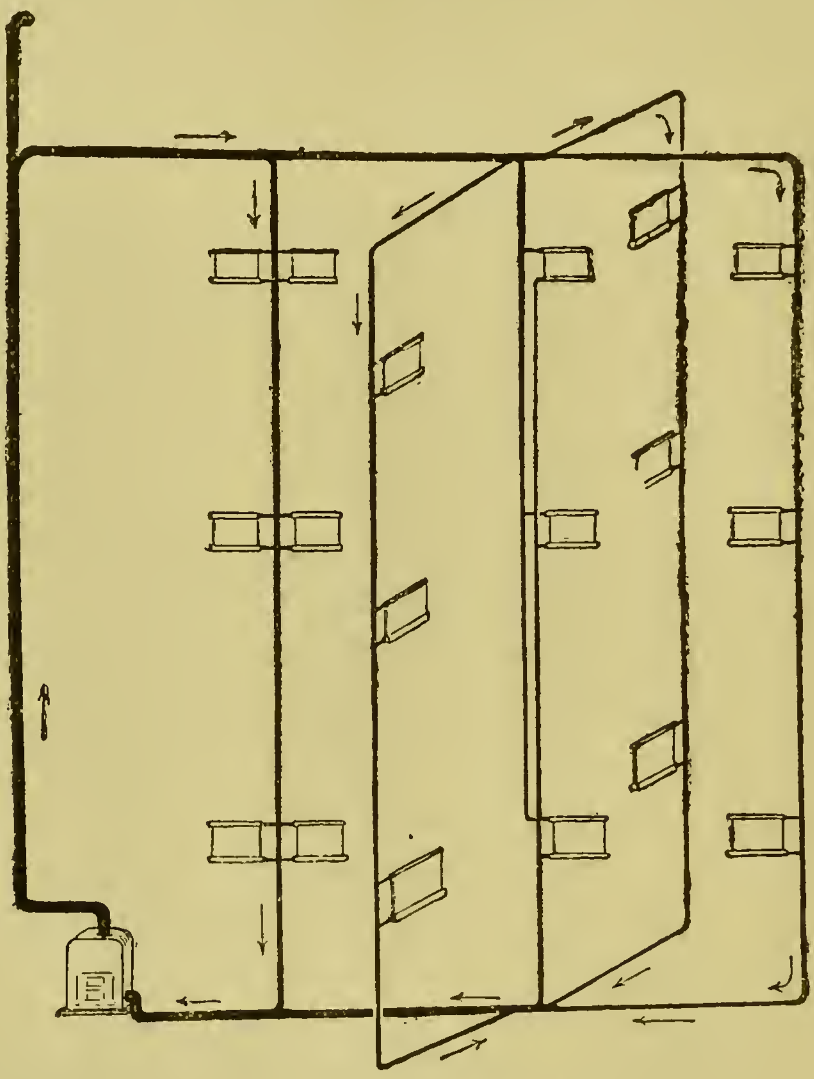

Fig. 247.

As stated, from the point at which the horizontal pipe is branched from the flow, the whole of the apparatus consists of return services, the water pursuing a descending course at every point down the building. It is practically a vertical one-pipe system—a one-pipe apparatus where horizontal mains are impossible—with the whole of the radiating surface on the returns. The writer has in mind a building that this apparatus was specially adapted for. It was a large furnishing establishment of five floors, with four distinct departments of about 50 feet by 50 feet on each floor. The floors were solid ironwork and concrete, and no horizontal pipes were permitted on the floors nor along the ceilings. This meant that horizontal pipes had to be totally absent from the business parts of the building. The overhead plan was so well suited, as it only necessitated a single vertical pipe in most of the angles of the departments, and a radiator connected up in each corner of every department on the different floors. The horizontal pipe appearing in this part of the work would, therefore, be limited to something less than 12-inch connections where the radiators are joined up to the vertical descending branches.

In the illustration the descending services are shown connected into a horizontal main return in the basement, this pipe being carried beneath the floor-level. This latter plan is only necessary when the basement space is of considerable value in being let as offices, in which case a large visible ceiling or floor-pipe would be objected to. Except for this, it is best to have a pipe of this size and importance somewhere in sight; but it might, if desired, be run in a floor-channel with grating over (as in church-work). This would make a neat job, and help to warm this floor. If this was done, there would still have to be some lengths of smaller pipe beneath the floor from where the descending branches reach the ground and pass to the main return. These, however, would not be objectionable, like burying a large pipe and all its junctions. The junctions or connections are, in fact, the parts which it is wrong to place completely and permanently out of sight.

The horizontal return-main would be graduated as to size the same as the flow pipe, being largest near the boiler, and smallest at the furthest point from it. There would be no advantage in having this pipe, say, 4 inches its whole length, although it may require to be this size from the boiler to the point where the nearest branch enters it. This piece of pipe has to carry the water from all the verticals, and be large enough to allow the water to come away from them with a sucessful degree of rapidity. On the other hand, the further extremity only receives the water of one vertical with three radiators on it. If these were of moderate size, then the vertical pipe would only be 1¼ inches, and the horizontal return need be no larger until the next vertical joins it. This graduation of mains will be found more fully described on pp. 344 and 361.

Assuming the different mains and branches are proportioned correctly, the degree of regularity with which this system of apparatus works is very pleasing and quite reliable. There is more than one thing goes to make the circulation perfect. In the first place, there is the utmost quantity of vertical pipe, which is always conducive to good results. The flow pipe which takes the ascending column of water can usually be taken by a nearly direct perpendicular route to its top extremity, and it is a full-sized pipe, giving the minimum of frictional resistance. There is also an absence of connections, and the detail of connections, that go to impede circulation. An important feature is that the maximum bulk of water, work, pipe, &c., are on the return part of the system which favours the descending motion in that part, and consequently favours the ascent of heated water in the flow pipe. Whenever there is a little problem in heating works in which some part of the apparatus has no circulation, or acts sluggishly, it is quite frequently traceable to there being something making the work of the flow pipe more difficult than it should be, and in no way favouring the descent of water in the return. In this apparatus it will be seen that the cold water cannot hang up in the radiators when there is a lighter column in the flow pipe. It simply drops or falls away from them, allowing hotter water to flow into its place. A difference of 10° causes a very rapid circulation in an apparatus erected on this principle. If any vertical branch gave more sluggish results than another, it could only be caused by a choked pipe (too small a pipe probably); but except some real fault exists, the results can be regulated to the greatest nicety by a stop-valve in each vertical pipe.

It will be seen that in the centre of the illustration one of the vertical branches is shown in duplicate, and advantages are claimed for this when a fair number of radiators exist in the line of one vertical service. By the addition of this pipe the water of each radiator is drained away and does not pass into the next, the contention being that after the water has passed through one radiator it must have lost heat, and is, therefore, scarcely suited to go through the next one. This is correct in a sense, but a very limited one, for if it was correct in practice no one-pipe system of apparatus would be of much use. No doubt people have in mind that mistake which can be met with sometimes (frequently a few years ago), in which the connections are effected so that the whole of the heated water is made to pass through the first radiator, then the second, next the third, fourth and so on. This is a distinctly bad way of doing the work, and there occurs an unmistakable difference in temperature between the first and the fourth radiators. In all one-pipe systems of apparatus it is essential that the main or sub-main pass clear by the radiator, as well as branching into it, so that it is only a proportion of the hot water that passes through any single radiator. By this plan there is scarcely a difference in heat between a first and a fourth radiator, certainly not sufficient to be perceivable except by a thermometer skilfully applied. Where, however, there are perhaps two large radiators connected to one vertical main on each floor of a high building, this auxiliary return or relief-pipe is desirable, although it need not commence at the top pair of radiators. It would suffice to commence at the pair below. The pipes might then be graduated similar to the plan shown with the system which follows this.

Fig. 248, another example of the overhead system, is introduced to show how it can be utilised for heating a suite of rooms or offices by radiators placed on the level of the floor that the boiler stands on. This is a requirement frequently experienced, but no other system of apparatus will meet it. In an instance like that illustrated the results will be quite satisfactory, and the apparatus should work as well as one in which all the radiation and service pipes are situated above the boiler, as is generally the case.

The graduation of size in the pipes is shown here again, and it cannot be too strongly impressed on the engineer that this graduation is necessary as well as desirable. In every apparatus the pipes must start from the boiler in full size for the work to be done, but not only is a saving effected by reducing the size as the work is passed, but more uniform results are had. In this example it is supposed that three moderate sized rooms are to be heated, requiring radiators of 32 feet, 35 feet and 40 feet surface. These can all be fed by 1-inch pipes (with 1-inch stop-valves), and for this purpose 1½-inch and 1¼-inch mains, as shown, are ample. If the rooms were grouped or close together then 1¼-inch mains would suffice from the boiler.

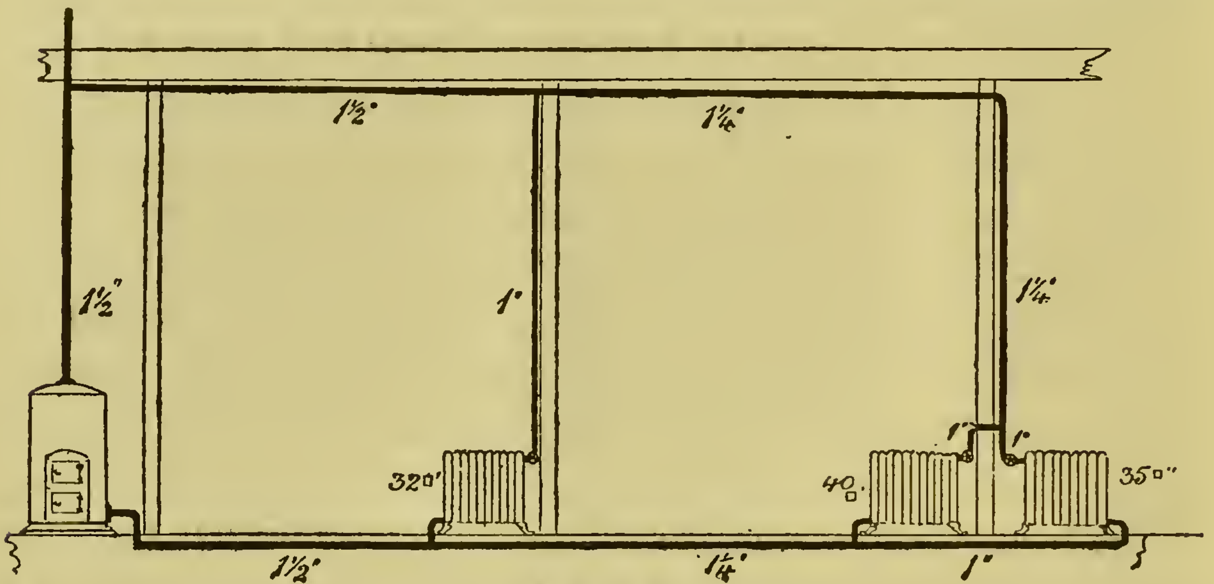

Fig. 248.

THE ONE-PIPE SYSTEM, WITH DUPLICATE AND GRADUATED MAINS.

This system of apparatus has no more simple or distinctive name. To the best of the writer's belief it has no title of its own, and is little practised in England as yet. Very little observation, however, is needed to show that it has real advantages, and that good results are obtainable from it. Good results, of course, include a sufficiency of warmth, but also mean, very importantly, regular and equable working at all points near to or remote from the boiler. It used once to be a somewhat valid excuse for indifferent results that the part of the apparatus in question was the furthest away from the boiler. This will not do now, as, with a suitable system of apparatus, *and a preservation of the heat in the distributing mains*, the furthest work should never fail. This is an opportunity to mention, also, that in heating a building—even a moderate sized residence—it is not necessary or even desirable

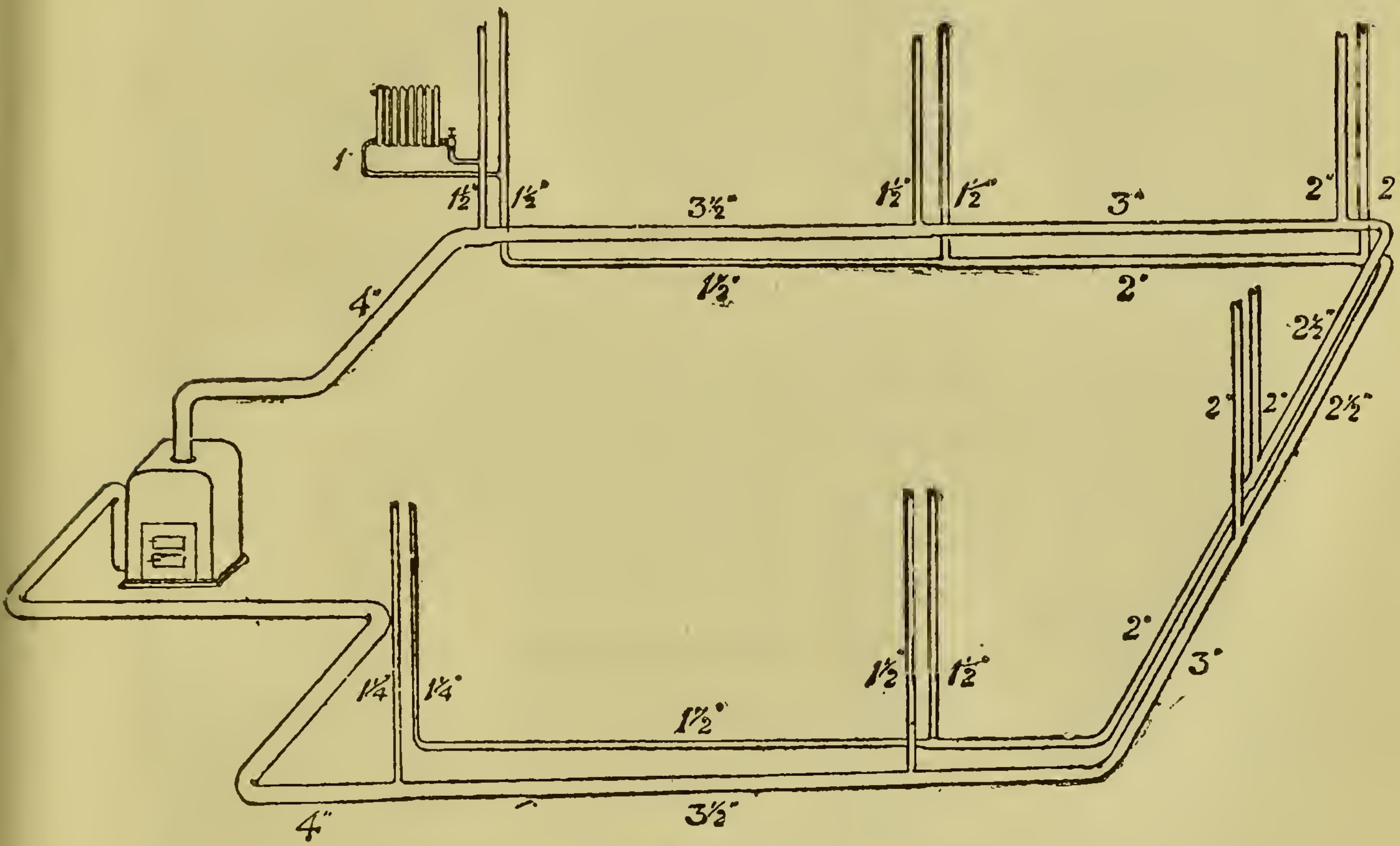

Fig. 249.

to follow out one system exclusively. Houses that are at all broken or irregular in design can sometimes have a combination of three systems with marked advantage, all working from one boiler, of course, and all can start from one primary main flow pipe if desired. An engineer often has opportunity to display much judicious ability in this.

Fig. 249 illustrates the system about to be described, and there is little doubt of its being the outcome of improvements on the ordinary one-pipe system. This latter system will bear the highest commendation when fitted in the manner already described; but there have been instances of engineers carrying things to extremes and putting a number of high vertical services on the one pipe, as Fig. 250. This is not a failure, but it leaves room for improvement in results in some cases. In fact, it is best when there are several floors, requiring vertical sub-mains to feed each floor, not to adopt the simple one-pipe system, but arrange for a two-pipe horizontal main, unless the "overhead" apparatus can be used.

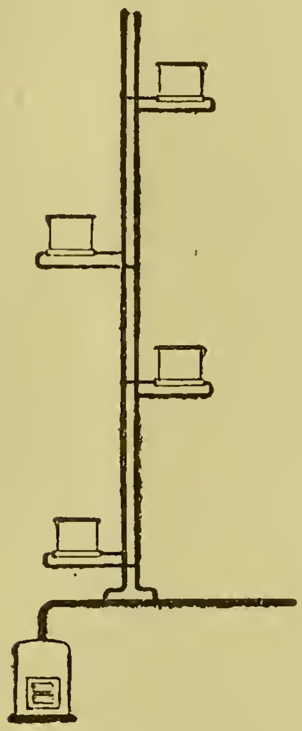

Fig. 250.

This duplicate one-pipe apparatus has its commencement and ending distinctly the same as the ordinary one-pipe system; but assuming the vertical sub-mains have each a good volume of cooled water to dispose of, the separate pipe, purposely to drain these services, is provided. It differs materially from the ordinary two-pipe system in the plan of boiler connection, as short-circuit is totally impossible in this. In the older two-pipe arrangement, the water, after circulating through the first branch, goes direct back to the boiler; so it is with the second, third and so on. If the pipes are not chosen with scrupulous care, or if one branch connection has to be awkwardly made (or a dozen other things that may occur), it greatly favours the circulation returning to the boiler from that point and failing to act successfully beyond it. In other words, the older apparatus is designed so that there are greater risks than with any other, that some part, particularly the parts furthest from the boiler, work sluggishly, or fail.

In the apparatus now being described, the auxiliary return commences at the first branch and travels with the flow pipe instead of passing back to the boiler. In fact, it is the only form of apparatus of the kind that has the water of the flow and return mains travelling in the same direction.

The graduation of size in the mains is based on the rule which applies to the older two-pipe apparatus, and the vertical sub-mains can be graduated to the amount of radiating surface they supply. In this apparatus, which is assumed to be of fair size, the flow pipe commences 4-inch. The first branch is 1½-inch, so that after passing here the main flow need only be 3½-inch until reduced again. The main return commences at this point, and it starts 1½-inch, as it has only a 1½-inch branch to drain; but it increases when it joins the next one, and has more water to carry. It increases on its journey round to the boiler proportionately with the decrease in the flow pipe, as will be seen.

The illustration describes a simple form of apparatus in which there are, apparently, no difficulties to overcome. The horizontal mains are carried around a basement below the building. The flow pipe would be given a gentle rise all the way to the furthest vertical branch, while the return should have a slight fall all the way from its beginning. This makes the pipes diverge and become wider from one another as they extend round the basement, and they may have a somewhat irregular appearance on this account. It is, however, the best plan to adopt with this system of apparatus. The flow and return pipes of any hot water apparatus can only slope in the same direction when the water within them is travelling in opposite directions.

In this form of apparatus it should be arranged that each vertical flow pipe have a stop-valve to control the circulation, and each radiator should have a stop-valve also, if the most perfect control of the warmth at all parts is desired. The graduation in size of the mains goes very far to effect equal results throughout the apparatus, as is intended; but it does not do away with the necessity of stop-valves entirely. With this apparatus, as with all others, it is very desirable that the mains be covered to conserve the heat within them. If this is not done, more trouble and expense is incurred than appears at first thought. Mains are seldom carried in the warmest situations—that is, situations naturally warm—so that they lose a deal of their heat. The flow main, of course, has the hottest water within it, and consequently is in a condition to lose heat the fastest when surrounded by cold air. The loss can be easily calculated, and will be found commonly equal to six radiators doing good work. This means waste of fuel as a rule, and also delays results when heating up; but most importantly it means serving radiators with water that has been reduced in temperature. Where mains are uncovered, or merely encased without packing material, they must be calculated as radiating surface when arriving at the size of boiler to work the apparatus. This may make an extra expense in the boiler greater than the cost of covering the pipes, apart from the better general results the covering ensures. By covering the pipes it is not meant that they have to be totally hidden in cases beneath floors or plaster-work. There are coverings now made that can be put up very rapidly, are as neat in appearance as the pipe itself, and which admit of any part of the pipe being exposed in less than a minute.

WORKING THE PRECEDING SYSTEMS OF APPARATUS UNDER PRESSURE.

This is a practice very rarely met with in England, but is adopted to a fair extent in America, though not generally approved by the best engineers there. The idea is to close the expansion pipe with a safety valve which can be weighted to any reasonable extent, and by this means admit of the water reaching a higher temperature than 212° F. Fig. 251 illustrates the general arrangement of fittings to effect this. On the top of the expansion pipe, which is the large pipe at the bottom of the illustration, is fitted a galvanised tank, as shown, and at the extreme top of this is the safety valve. To prevent the pressure obtaining relief by forcing water through the cold supply service, a check-valve (stop-back valve) is fitted in this service. The cold supply is shown carried into the expansion pipe, but it could be carried into the tank, if desired. The water gauge shown on the tank is a desirable fitting, though not absolutely necessary.

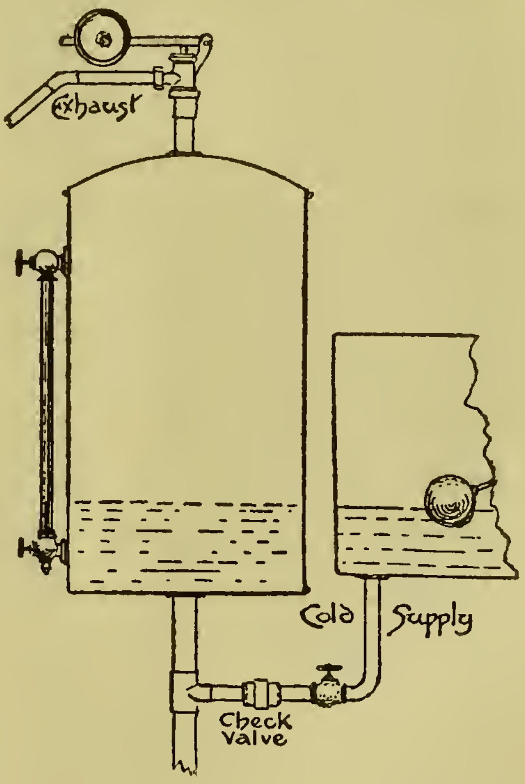

Fig. 251.

In the next chapter it will be seen that the ordinary boiling temperature of water, 212°, can be exceeded when water is heated under pressure, and with the safety valve set to 10 lbs. per square inch (above atmospheric pressure) 240° F. can be obtained. By this means, it is contended, an economy in radiating surface can be effected of something like twenty per cent. A radiator, therefore, need only be of, say, 40 feet surface, to do the work of a 50 feet radiator. Added to the saving by a decreased radiating surface for given results, proportionately smaller pipe can be used; in fact, the size of pipe can be reduced out of proportion as the circulation is more rapid, and has a little higher motive power.

A more detailed description of this need not be given, however, as it is an arrangement that cannot be commended. Enough has been said to show how the results can be effected, should any one desire to try it, but there are objections which can be summed up as follows :—

That all joints, connections, castings, valves, &c., require to be very sound, or leakages will be developed that would not appear in an ordinary low pressure apparatus. That should a burst occur by any means when the temperature is well above 212°, the escaping water will instantly become steam with serious effect. That for safety, only the safety valve can be relied on, as no pressure can be relieved by way of the cold supply pipe, and safety valves, unless in regular frequent use, are liable to become stuck. That the radiating surfaces are more dangerously hot, should the hands come in contact with them. That greater attention at the fire is needed if the high temperature is to be sustained, as must be with the decreased radiating surface, when the weather is severe. Also that the Building Acts and the bye-laws of most district authorities class this as a high pressure apparatus, no part of which may come within 3 inches of woodwork. (See chapter on the Metropolitan Buildings Acts.) It is also important that the expansion tank be put on a part of the apparatus that cannot be cut off from the boiler by stop-cocks. If these precautions, as to strength of joints, location of pipes, &c., have to be observed, then the regular high-pressure, or modified high-pressure systems had better be adopted. These form the subject of the next chapter.

CHAPTER XX.

THE HIGH PRESSURE SYSTEM OF APPARATUS.[*]

Phenomena of Ebullition—Heating of water in sealed vessels—The high pressure system—Size of pipe—Boiler coil—Motive power—Expansion pipe and its use—Filling—Joints—Stop-cocks—Testing—Advantages and precautions—Frost—Non-freezing fluid—Uses of this system—Proportions—Temperature and pressure table—Modification of H.P. apparatus—Regulating valve—The application of the Building Act—Example apparatus.

It is, of course, common knowledge that the temperature at which water boils is governed by the pressure of the atmosphere. When water is heated in open vessels, or in any apparatus that is open at the top, as a general result the boiling commences at 212°, this being when the atmospheric pressure is 15 lbs. to the square inch, viz. at sea level. If we boil water at some distance above the level of the sea, on a mountain or very elevated piece of land where the pressure of the atmosphere is less, we shall find that ebullition takes place at a lower temperature. On the other hand, if the boiling takes place below sea level, in a deep mine where the pressure is greater, the water reaches a higher temperature than 212° before boiling commences. In all these cases the heat of the water at boiling point represents its greatest heat, and it cannot, in open vessels, be made any hotter. This is the case with low-pressure heating works; as by urging the fire we can heat water to 212° temperature, but no higher.* This goes to show that in open vessels, or any apparatus open at the top and under the free influence of the atmosphere, the boiling and consequent maximum temperature is limited to about 212°.

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[*] This mode of heating was introduced in a practicable form, in fact invented, by A. M. Perkins in 1845, a patent having been granted him in that year. His name has become so associated with the apparatus that it is now more commonly known as Perkins' System than by any other title. No one has brought it to such a degree of perfection, nor adapted it successfully to so many uses as the firm that bears the inventor's name (A. M. Perkins & Son), and it is worthy of note that many of the apparatus erected so many years ago are now in use and doing good service. The firm still carries on business, and continues to carry out the principles of the original invention.

The high pressure system, and any modified form of it, have their principle based upon the fact that in a sealed vessel or appliance—one that has its contents entirely excluded from the influence of atmospheric pressure—it is possible to raise water to a temperature far exceeding 212°, and without introducing any objectionable features, except the great expansive force exerted by the water and other quite natural phenomena, which have to be provided for. At present there are comparatively few engineers who make a speciality of these works, but undoubtedly the number will increase when some of the prejudices that exist (chiefly in the minds of the public) have been disposed of.† This system was introduced about 1845, but it always seems to take a great time for introductions of this character to gain a firm footing, even though they possess merit, as this undoubtedly does.

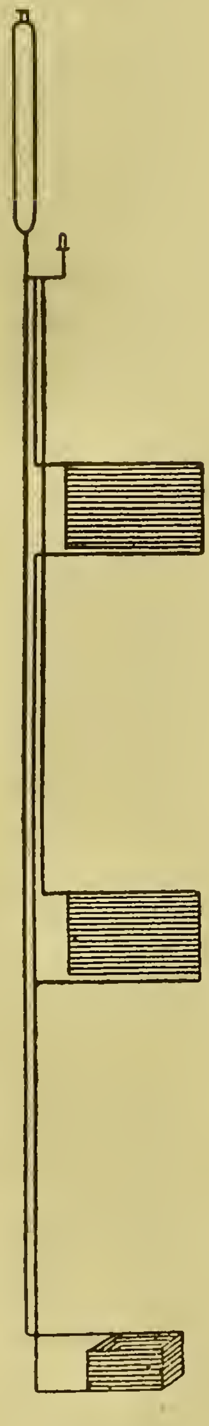

Fig. 252.

Fig. 252 illustrates a small apparatus of this kind, the illustration being given here to simplify the explanation. No boiler is used in this system, as, in the first place, it would be a source of weakness; and, secondly, it would not present such valuable heating surface as a coil of small pipe. There is no need to fear that failure may ensue owing to the small pipe being choked with deposit or dirt, as the apparatus being made perfectly air and water-tight (to withstand a high pressure) obviates this, it being impossible for any such accumulation to occur. The pipe, forming the boiler, is coiled into any form to suit the shape of the fire-box, very usually square or oblong as shown; the lowest pipe is connected with the return, while the top pipe is continued as the flow. The pipe constituting the boiler, that used as services, and that made into radiating coils, are all of the same size and material, the whole being alike from top to bottom except the expansion pipe at top, which will be referred to.

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* Table I. of the Appendix gives the temperatures that can be obtained with certain pressures; also see a few pages later in this chapter.

† Those in a small way of business would be deterred by the necessity of having a special outfit of tools. The ordinary hot water fitter's tools are not suited for this work, as will be seen directly.

Sometimes, when the work is of such description or magnitude that two or more flow pipes are considered necessary, the pipes forming the boiler are made up in two or more sets, inter-coiled with one another; or some engineers prefer to use branch services from the one boiler coil, no rule being laid down in this respect.

From the boiler upwards the customary flow and return services are carried wherever required, governed by the same rules and features that have been spoken of fully in low pressure work; but as the temperature of the flow pipe is very high, and that of the return pipe rather low (comparatively, as with these small pipes the water loses heat very rapidly, also see p. 270) the speed of circulation—the motive power—is very great. A few dips in the pipes are not considered such great drawbacks as with low pressure works, and not so much thought is always given as to whether a doorway or such obstruction exists in a room, for the pipes can be readily dipped under it if it is any particular convenience so to do. The great objection to dips in low pressure pipes is that on one side the pipe gets air-locked, as has been explained; but this cannot happen with high pressure works, as they are first pumped full of water and all air thus expelled, and then sealed up. After this no fresh air can be absorbed by the water and carried into the pipes, as happens with a low pressure apparatus.

At the extreme top of the apparatus, just above the highest point at which the water circulates, is fitted an expansion pipe, a piece of a larger sized tube usually (as shown), or it may be a continuation of the small pipe, only in a greater length, as this expansion chamber has to bear some relative proportion to the size, i.e. the contents, of the other parts of the apparatus. The utility of this chamber makes it necessary to explain one of the chief features in the system, viz. the great expansive force exerted by water at a high temperature, as without confinement under pressure this temperature would not be reached. It must be borne in mind that it is the pressure wholly and solely that permits of the increased temperature being attained. At normal atmospheric pressure the highest temperature for water is 212°; at pressures above that of the atmosphere, water can be heated beyond 212° to a certain fixed extent, as is given in Table I. in the Appendix.

When water undergoes an increase in temperature, there also takes place an increase in bulk, and this increase may be considered irresistible, for water is not elastic, and an apparatus, if quite filled with water and sealed up, would be fractured long before its contents acquired a great heat. To obviate this the expansion tube is provided. In the illustration it will be noticed that the filling opening is situated just above the highest point of the circulation, but just below the expansion pipe. When the water is passed in by this filling tube, the air is, by the entry of the water, expelled, it passing out through the expansion tube which is kept open at the end when charging. When the whole of the apparatus is charged it will thus contain water up to the level of the filling opening, but none in the expansion chamber. This is the condition it should be in when the cap or plug is secured, and the hitherto open end of the expansion tube closed, so that before the fire is lighted there is no water, nothing but air in the tube.

Upon the application of heat to the boiler the water undergoes the above-mentioned expansion, and having no means of relieving itself in the lower part of the apparatus, it begins to force itself up into the expansion chamber, partially filling it. In saying it *forces* itself up into the chamber, a correct term is used, as it cannot enter freely by reason of the air that has been left confined there, and offers resistance to its entry; but the water possesses the greater force, and compresses the elastic air into less space, and this bulk of air expands or contracts as the temperature of the water, and its consequent expansive force, is lessened or increased. In acting in this way the air does great service on account of its perfect elasticity, as when compressed it exerts pressure upon the water, and by the rule stated permits of its gaining the high temperature required, yet by its nature it does not readily permit of a fracture, it acting so excellently as a spring or cushion.

It will be seen from this that the size of the expansion chamber could be varied, and so to a modified extent regulate the heat of the water, but this has not been found of practical service, and where it is wished to limit the heat a reduced boiler coil can be resorted to, or a kind of valve used, which will be referred to presently. This valve is much in favour, as it prevents the apparatus overheating, which it is apt to do if tended by inexperienced persons.

The pipe used in this work is of small size compared to low pressure works, and is made of wrought iron of a special strength,* the size, material, and strength, all being those best suited to withstand the great strain that has to be borne. The pipe which is almost universally used measures $\frac{7}{8}$ inch diameter inside, and $1\frac{5}{16}$ diameter outside, having a substance of metal of $\frac{1}{4}$ inch bare, being stouter than the steam quality tube referred to on p. 275, and proportionately more expensive. The joints are made without any packing material, one end of the pipe being finished with a conical edge, as Fig. 253, the opposing end being finished flat; this would not be sufficient only that one end has a contrary thread (screw) to the other, right and left handed, and the socket is tapped in the same way. In turning the socket the pipes are thus caused to approach each other, the ends ultimately meeting, so that the conical edge impresses itself into the opposite flat edge, and this makes a very sound joint.

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* The special pipe for this work is readily obtainable from any good manufacturers.

A sound joint is very necessary as will be understood, but it has to bear a still greater strain when testing, it being customary before sealing up to test the whole apparatus to a pressure of from 2000 to 3000 lbs. to the square inch This ensures its being sound when working, for it should be remembered that the coil in the furnace is considerably weakened by the heat it is subjected to, and that iron is unable to withstand so great a strain when hot as when cool.

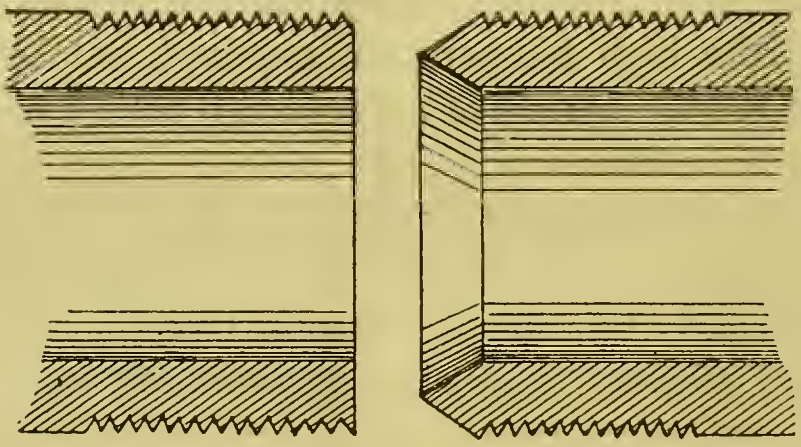

Fig. 253.

The small quantity of water that an apparatus of this kind holds, and the rapid circulation, together effect very rapid results, and on this account it is especially adapted for very many purposes, but it must not be overlooked that hot water systems which attain their maximum heat rapidly, just as quickly become cool as the fire goes down. This, however is no drawback, as it can be readily obviated by constructing the furnace so that it will hold a full charge of fuel, which with a usual amount of attention to the damper, &c., will heat the boiler coil regularly for a considerable time.

The smallness of the pipe also serves another useful purpose, as by its means we are enabled to introduce radiating surfaces in positions where a large cast pipe would be objectionable, or, perhaps, impossible. For instance, in this work the heat-distributing pipes are very commonly placed behind skirtings, in a shallow wood case beneath a window. Also, in similar positions (inaccessible with a large pipe) where they can be used for warming inlet fresh air, as Fig. 254. In calculating for these small pipes it does not become necessary to allow three or four of these to do the work of one 4-inch pipe of a low pressure apparatus, as the higher temperature compensates to a very great extent for the reduced size, i.e. radiating surface, and in many of these works a pipe of $\frac{7}{8}$ inch internal diameter is calculated to do the work of one of 2-inch diameter of a low pressure system.

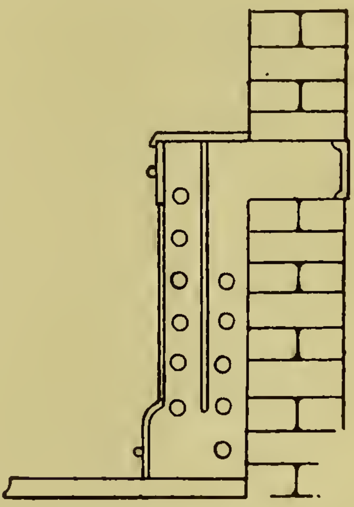

Fig. 254.

It becomes somewhat necessary to run these pipes in unexposed places, not only because they are about as ill-looking as cast pipes, but also because of their heat, which would be felt severely if touched by the hand ; and in public places, however unimportant, this must be guarded against. Coils can, of course, be placed in the customary iron coil cases if it is not desired to place the pipes in channels. If channels are adopted this system stands at a little advantage, as a channel of an ordinary width will take six pipes (if needed) side by side, which is preferable to putting pipes beneath one another, as they cannot then readily be kept free from dust, and the lower pipes do not render the service the top ones do. These channels, therefore, need only be about 3 inches deep.

This system is never adopted for horticultural works,* as it would not give quite the satisfactory results that we get with low pressure, however well it might be tended. In the first place the greater temperature would necessitate keeping all plants and such life clear of the pipes to more than what would be considered a convenient extent; also it would not give such an equable temperature owing to the heat of the pipes fluctuating so quickly with the fire,† and many plants are very susceptible to changes of this kind. Further, the great heat of the pipes (300° to 350° for general purposes) is apt to vitiate the air to a trifling, sometimes to a noticeable extent, by decomposing particles of organic matter that may fall and rest upon them, and although this would not appear in greenhouse work to quite the extent it might in building works, it would still be objectionable in the gardener's eyes.

Much discretion must be exercised in introducing stopcocks in this high pressure system (which has no regulation valve), as it can be readily seen that on closing off a good portion of the apparatus, say one-fourth or a third, it would practically convert the apparatus into one which had a boiler coil disproportionately large. The fire would require to be reduced at once, otherwise a much higher temperature would be felt at the remaining circulating pipes with increased strain, and so injury might occur. There is a certain amount of danger should a pipe burst when the water is at a high temperature, and instances of rather serious injury from this cause occur occasionally. When water is above 212° F., and becomes released, it is instantly converted to steam, and should a rupture occur in a boiler tube, even a large stoke hole or boiler room will be filled with steam in a moment. In the last case brought to the writer's notice, the attendant, who happened to be in the small cellar where the boiler was, received a severe scalding and was rendered insensible. It might have been worse, only that his cry was heard and a prompt rescue effected.

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* The writer has never met with an instance. Conservatories are, however, sometimes warmed from the house service.

† The particular gain with large pipes in horticultural work, is that the greater bulk of water does not so readily show an increase or decrease of temperature as the fire varies, and the air of the greenhouse is of a regular heat.

It is almost needless to add that an apparatus of this kind, holding so little water, if completed in severe weather, should not be charged unless the fire can be lighted immediately afterwards; even then it is not a good practice to do so unless it can be charged with a non-freezing solution at once, as the frost will affect an apparatus like this very quickly. Freezing its contents will not only cause a fracture by its own effect, but cause mischief by stopping communication with the expansion tube. A non-freezing solution is of particular value in these works, as should the fire be left out for one day, or the matter of a few hours in severe weather, the damage will be done; or if a house was left unoccupied the apparatus could not escape, unless emptied—a very troublesome remedy, as will be understood.

The high pressure system is of great use for drying rooms and closets, and it is even applicable to japanning ovens; all these purposes are fulfilled more effectually by this apparatus than by the low pressure,* but japanning wants the highest temperature of all, viz. about 400°.

The proportions of the apparatus, to effect given results, appear on page 381; they will bear variation for special reasons. It should not be attempted to increase the proportion for furnace coil, nor to decrease the expansion tube, except for some very particular purpose, and under the advice of a competent engineer.

The furnace coil can be obtained, made to the size and shape decided on, from the tube makers, but if it is not desired to build the furnace in brickwork the complete coil in an independent casing can be had, as Fig. 255.† This is a very desirable arrangement, saving labour, and having a superior appearance when fixed.

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* A low pressure apparatus would be useless for japanning purposes.

† As supplied by Wontner, Smith, Gray & Co., Finsbury, London, E.C.

The pressure and temperature table (Lardner) is as follows :—

Pressure in lbs. per sq. in.	Atmospheres.	Temperature. Degrees Fahrenheit.	Pressure in lbs. per sq. in.	Atmospheres.	Temperature. Degrees Fahrenheit.
15	1	212·00	240	16	398·48
30	2	250·52	255	17	403·88
45	3	275·18	270	18	408·92
60	4	293·72	285	19	413·78
75	5	307·58	300	20	418·46
90	6	320·36	315	21	422·96
105	7	331·70	330	22	427·28
120	8	341·78	345	23	431·42
135	9	350·78	360	24	435·56
150	10	358·88	375	25	439·34
165	11	366·80	450	30	457·16
180	12	374·00	525	35	472·64
195	13	380·66	600	40	486·50
210	14	386·96	675	45	499·10
225	15	392·90	750	50	510·62

The modified form of the high pressure apparatus, a form that will, perhaps, supersede the genuine and original system for residential and most building works, is practically identical with the other, except for the introduction of a regulating valve at a point that will be presently indicated, and, in the majority of cases, the absence of the expansion pipe. The construction of the boiler coil and furnace is the same ; the arrangement of services may be the same also, but the regulating valve permits of a free use of stop-cocks wherever desired without being liable to cause damage.

This valve practically consists of a safety valve and inlet valve combined, the former permitting the apparatus to be relieved when the pressure is excessive (the valve can be set to open at any pressure desired *), by allowing some of the water to escape. The inlet valve permits water to re-enter the apparatus when its contents have cooled and are upon the point of creating a vacuum by the contraction of the water as it loses heat and bulk. Fig. 256 will give an idea how this is effected, the illustration showing the working principle that is embodied in the various valves used. The valves

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* The preceding table shows that a valve weighted to 135 lbs. to the square inch would limit the temperature to 350°.

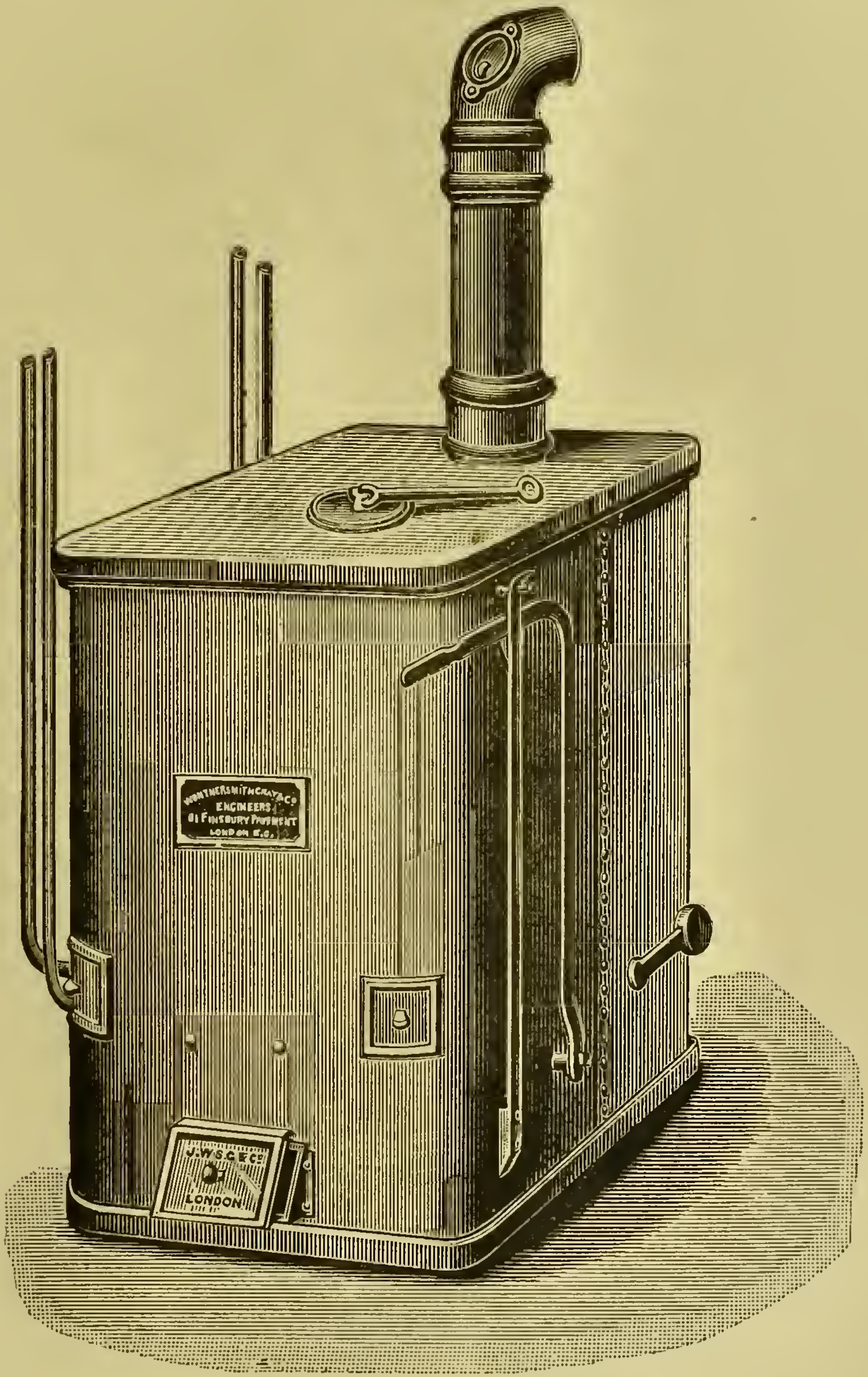

Fig. 255.

vary considerably, as many engineers of these works usually have their own pet notion, more or less complex. The great enemy to their efficiency is the perpetual expansion and contraction brought about in the valve itself by the almost constant outflow of hot and inflow of cold water, for every variation at the furnace causes one of these actions to take place at the valve. There are few valves that are perfect in this respect.

The valve is placed in a moderate sized cistern at the highest point of the apparatus, as Fig. 257, above the circulating pipes, and although the same water that is expelled is afterwards drawn into the apparatus again, it will be found necessary to replenish the cistern occasionally.

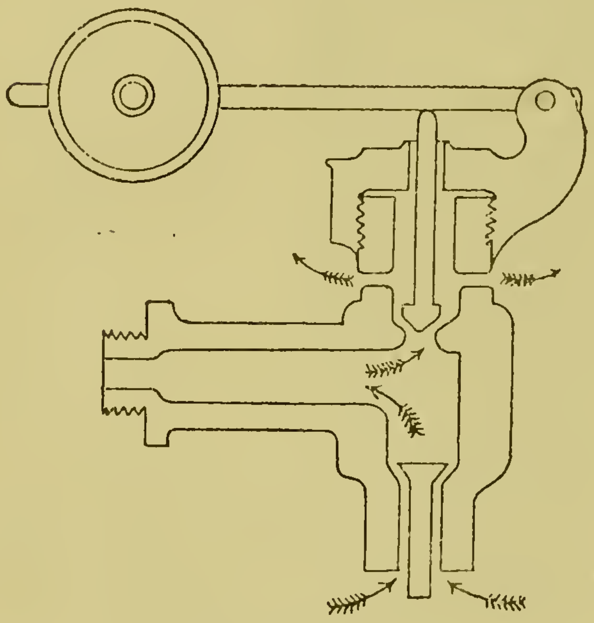

Fig. 256.

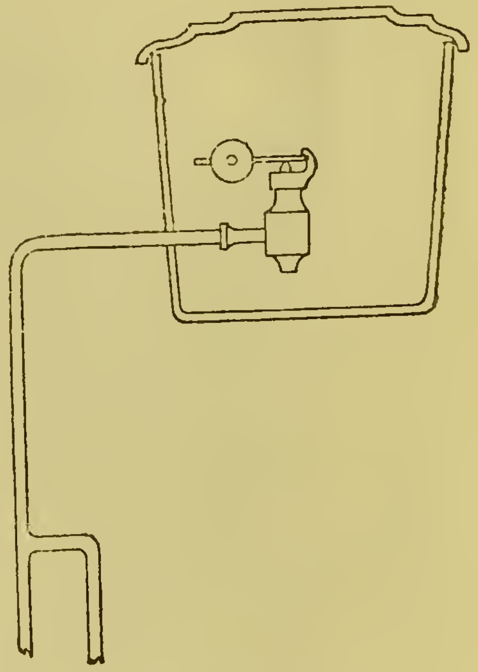

Fig. 257.

The pipes have to be erected in a manner that conforms with the Building Act, which rules that they must be 3 inches clear from any woodwork or inflammable material. The normal working temperature for the high pressure system of apparatus is about 350° F., but by careless stoking, that is, over-firing, 600° can be reached. No one seems willing to say whether this style of apparatus has ever reached a temperature sufficient to ignite paper or wood, although the writer has made enquiries. In the hands of skilled engineers, however, the high pressure apparatus can be erected with the boiler coil and expansion chamber so arranged that no danger of the kind could possibly occur. The Section of the Building Act which governs the erection of this apparatus is given in the last chapter of this book.

Fig. 258 is an example of an apparatus heating a large hall and two rooms leading from it. In this case two expansion pipes are provided, one on each of the coils furthest from the boiler. This is a very desirable provision if arrangements are made to shut off either half of the apparatus. It is better, however, to arrange for the expansion pipe to come in a position that cannot possibly be shut off even if every coil was accidently or intentionally thrown out of use while the fire was alight.

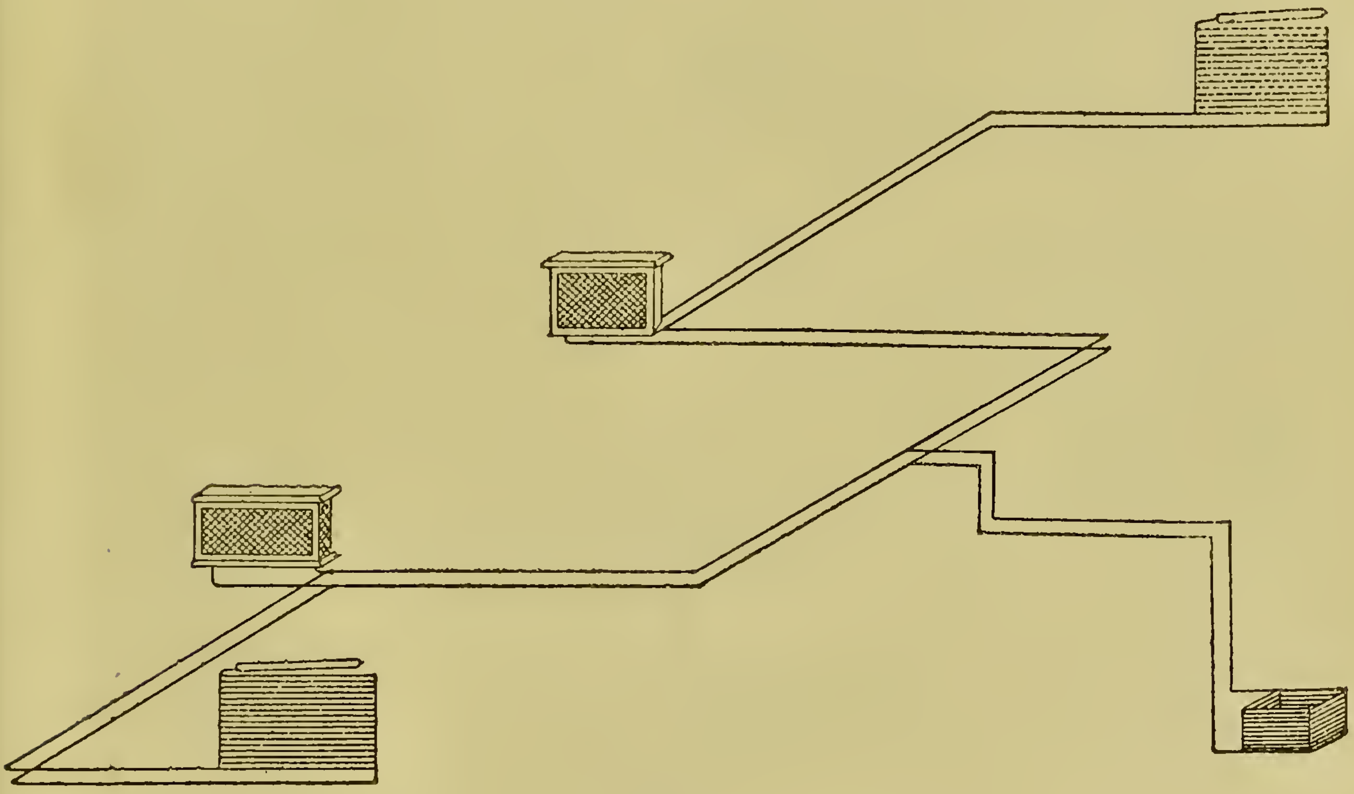

Fig. 258.

Expansion pipes are always situated at the highest point of the apparatus. They would afford the required relief at any other point of course, but there would be the liability of air working out of them into the circulating pipes. Even here the air would continue its useful work as a cushion, but it would probably ruin the efficacy of the circulation.

The filling is sometimes effected from the filling cap at top, shown close beside the base of the expansion pipe at Fig. 252, but more usually it is done from an opening provided close down beside the boiler as Fig. 259. The water is pumped in, and its ascent from the lower point is more favourable to the complete expulsion of air from the circulating pipes, than if the filling is done from the top. The upper opening is then utilised as an overflow aperture. This last illustration shows a dip, marked D, in the lower return pipe. This is put with the view to prevent a retrograde circulation when the lower pipes of the boiler coil are the hottest. In a simple form of apparatus as this is, it would hardly matter which way the water circulated, but in a more complex one it would have an important effect.

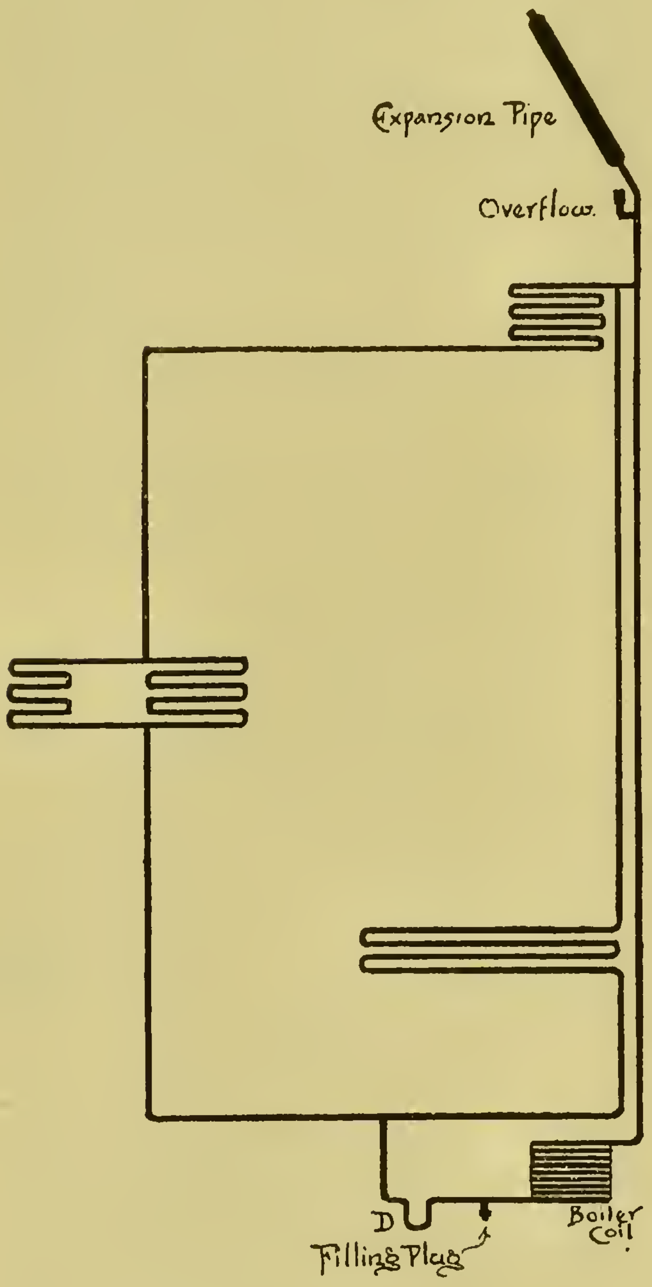

Fig. 259.

The following quantities of radiating pipes must be as nearly as possible equal flow and return services. If it is vertical work with the flow pipe not utilised for radiating purposes, then this pipe must be covered to prevent loss of heat, or less effective results must accrue.

QUANTITIES.

Temperature required.	Quantity of pipe ⅞ in. internal diameter to each 1000 ft. cubic capacity in an ordinary brick-built room.	Proportion of pipe in apparatus to form boiler coil.	Purpose for which the temperatures may be required.
Deg. Fah.	feet.		
50	12	$\frac{1}{12}$	Coach-houses, workshops, stores, &c.
55	14	"	
60	17	$\frac{1}{10}$	Public places, sleeping apartments.
65	20	"	Living rooms.
70	24	"	
80	34	$\frac{1}{9}$	Drying rooms. (If for wet goods requiring rather free ventilation, the quantity of pipe must be greater, to maintain the temperature.)
90	46	"	
100	65	$\frac{1}{8}$	
120	90	"	
150	125	$\frac{1}{7}$	
200	200	$\frac{1}{6}$	

For the expansion tube allow as much pipe as given above for boiler coil, or its equivalent internal capacity in larger tube.

CHAPTER XXI.

WARMING BUILDINGS BY HEATED AIR.

Unfounded prejudice to this mode of heating—Warming air by hot water pipes or radiators—Warming air by stoves—Semi-direct radiators—Indirect radiators—The utility of gills on stoves—Musgrave's stove—The Gurney stove—Grundy's calorifier—Mechanical distribution of warmed air—Air propellers.

It is doubtful whether to the average Englishman anything implies a greater want of health and salubrity than warming a house by heated air. It is only unfounded prejudice that can account for this, and not experience of good or even fair work, yet no prejudice shows signs of dying harder than this. It is difficult to account for this prevailing idea of the unhealthfulness of warming buildings in this manner beyond saying it is prejudice, but what this latter is founded on is difficult of comprehension. This method of warming buildings has hitherto been so little practised in England that only a very small number of people have ever seen such an apparatus apart from having personal experience of it. Perhaps the makers of open grates are accountable for the general opinion, but that it is wrong every one having a properly constructed apparatus can give testimony to.

There are, broadly, two methods of executing this work, one having hot water—in pipes or radiators—as the heating medium, the other depending on a suitably constructed stove. The writer has found that in proper hands there is little choice as between the general results of the two methods, but amongst architects and others there are widely different opinions held. For residence work they probably lean towards hot water the most, but those who use the stove apparatus have as strong a good opinion for their preference.

Amongst the examples of radiators in Chapter XVI. were several described as "ventilating." The American terms "direct-indirect" or "semi-direct" are being frequently used for these, meaning that the radiators do partly direct heating work by standing in the apartment to be warmed and distributing heat there, besides warming new air that is introduced from outside. This latter ability constitutes it an appliance for warming a room by heated air, and it is this which is termed indirect heating.

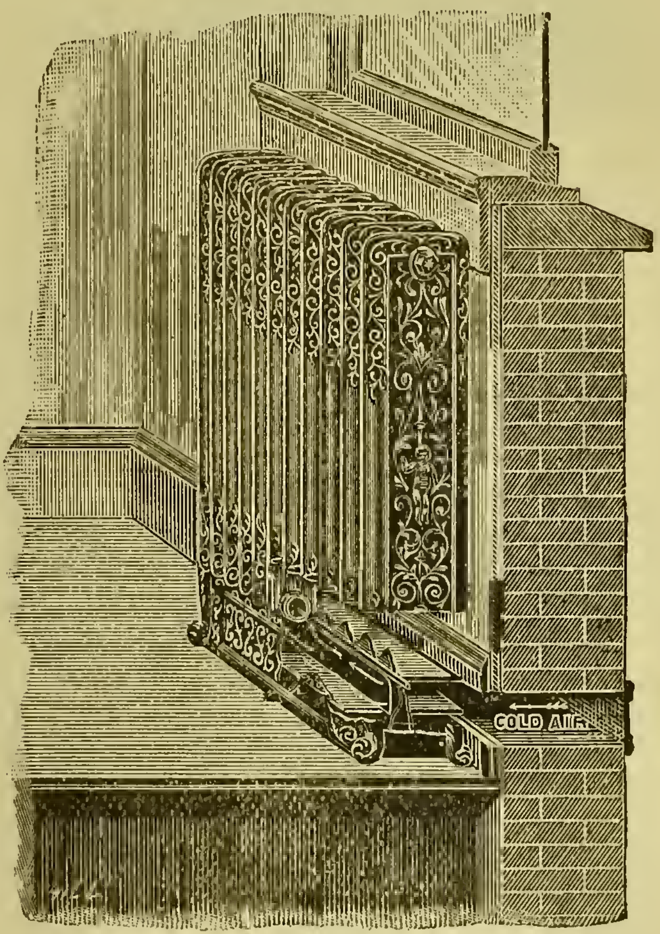

Fig. 260.

Fig. 260* illustrates a ventilating, or direct-indirect, radiator in position, and shows the method of connecting its base with the outer air. There are several devices for controlling the inflow of air, this one being by a small lever which projects from the base at the floor line and is operated by a person's foot.

In this illustration, Fig. 260, the cold air inlet is shown level with, in fact slightly above, the floor line. If requisite, the base can be arranged for a floor opening as Fig. 261. In this it will be seen the cold air inlet is in a line with the space between the joists, and a hole is cut in the floor that the air may rise through the radiator. It is necessary to shut off the space between the joists beyond the hole in the floor as shown. The object in regulating the air inlet by a valve in the radiator base is that in the coldest weather the supply of air is intended to be materially checked, otherwise an over-powerful radiator would be necessary to heat up the full volume of air passing through. Again, the inlet opening would be regulated according to the state of the wind outside, also according to the outlet ventilation. If the latter is full and active the inlet would probably require checking at all times. When the radiator is out of use in summer its ventilating capabilities can be made use of and regulated according to the weather. The front of the base is easily removable for periodically dusting and cleaning out dirt material carried in by the air, but the necessity of this can be reduced by putting a wire-gauze screen at the inlet opening. This will prevent insects passing in and also modify the strength of the wind if blowing strongly against that side of the house.

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* This and the three succeeding illustrations are by the American Radiator Company, 143 Queen Victoria Street, London, E.C.

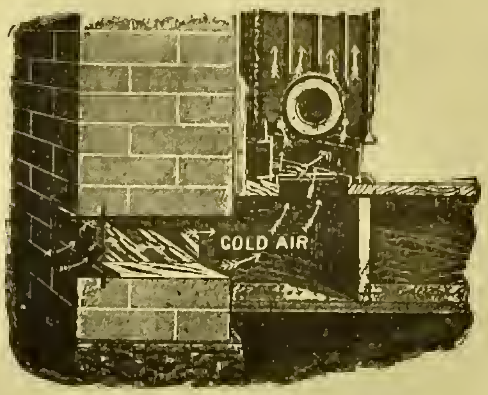

Fig. 261.

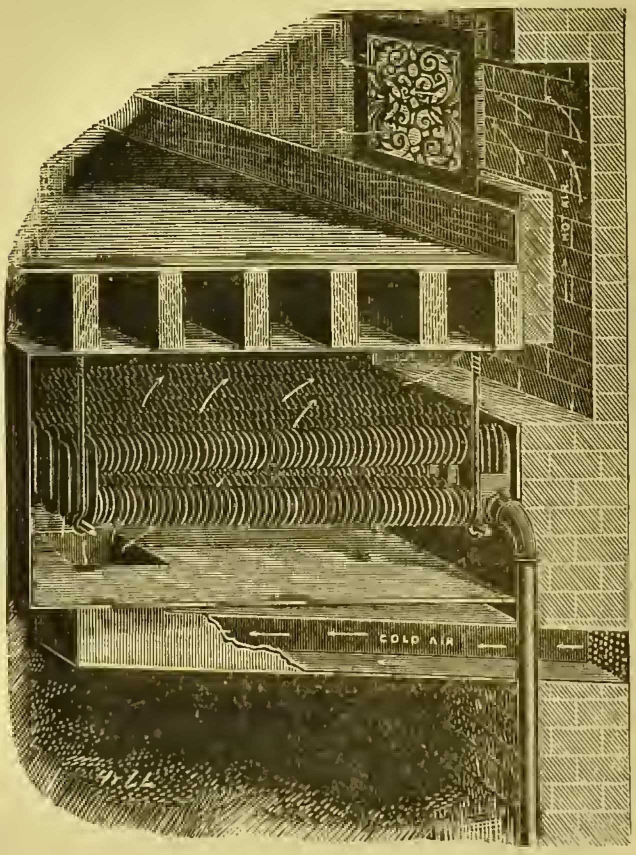

Fig. 262.

To warm the air without visible pipes or radiators, the heating medium is fixed in a wood, metal, or brickwork chamber, this having a cold air inlet something as already described, and the warm air outlet or outlets are disposed as is most convenient. The latter must discharge the warmed air in an ascending direction, as this method of warming works by gravity only, unless the job is big enough, or otherwise necessitates mechanical air propellers. With gravity as the motive power the air conduits may be likened to chimneys, they may ascend in any direction, but on no account dip downwards except under some specially favourable conditions. Horizontal conduits are scarcely permissible, and all should rise more or less wherever they are carried.

Warming air by means of hot water is divided into two methods. In one the pipes or radiators are encased beneath the floor of each room to be heated, as Fig. 262 ; in the other they are confined to one chief or central chamber, and warm air conduits are carried from this point to the various places the warmth is required at. In some cases a combination of the two arrangements is effected, this being quite feasible and very practical when meeting special requirements.

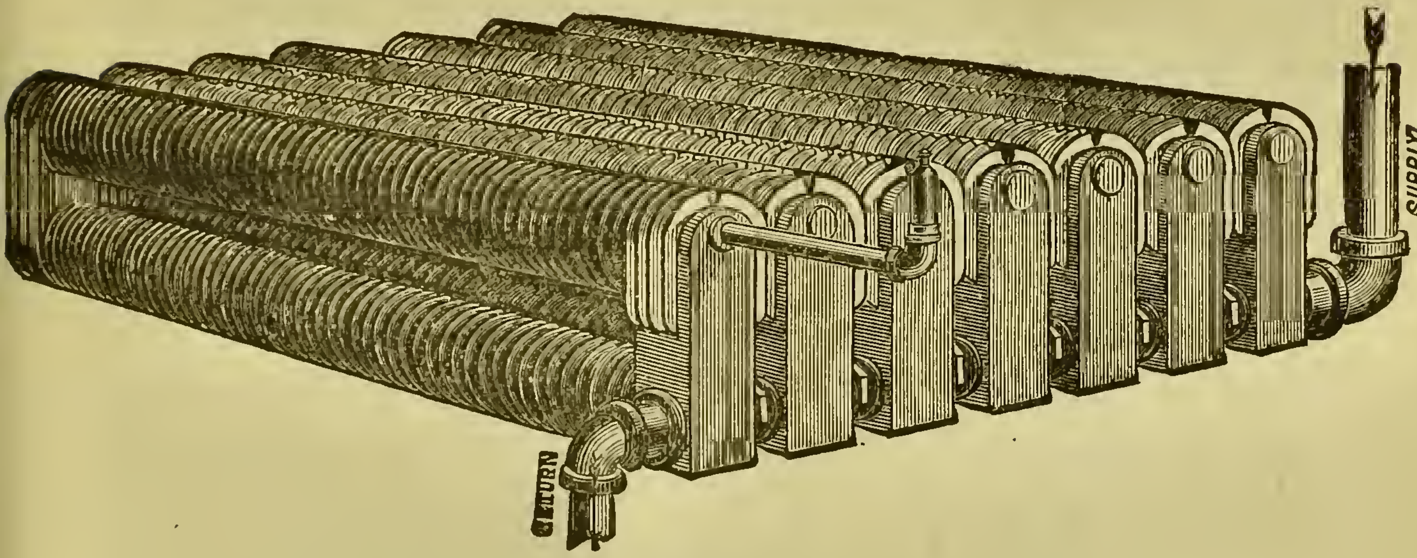

Fig. 263.

With the example Fig. 262 very little explanation is needed, as the illustration is self-descriptive. In this the warmed air is shown passing by a channel cut in the wall and a register grating in the skirting board. This plan is sometimes considered neater than a floor grating, but it involves more work and expense. If a room is wholly carpeted a floor grating may not be desired, and, again, it is considered that with the latter the warmed air is projected more to the ceiling than with a register in the skirting. The advantage or disadvantage of this will depend on the position of the outlet ventilation aperture, as will be explained later.

Fig. 263 illustrates an indirect radiator consisting of a stack of sections nippled together, the full size of the radiator being therefore made anything that the work demands. This shows a seven section radiator, similar to that shown in Fig. 262, each section being 36 inches long, 7½ inches high and 3¼ inches wide. Each section contains 12 superficial feet of radiating surface, but this is not prime surface, being largely composed of solid gills as will be seen. Extended surface such as gills, pins, &c., do not bear such a high work value as prime surface.

By referring to Fig. 262 an important feature will be seen, this being the disposition of the inlet and outlet openings of the radiator chamber in their relation to one another. To obtain the best results it is important that the cold air be made to pass over the whole heating surface, if possible, before it reaches the warm air outlet. Every care must be exercised to effect this.

In those works which have the stacks of pipes or radiators in one central chamber, the boiler is commonly made to do duty as radiating surface also. That is, the boiler is set in the heating chamber, the boiler front, with its stoking and cleaning doors, appearing only on the outside wall of the chamber. From a fair sized boiler, with unprotected outer surface, an amount of heat can be obtained, as much as from a good sized stack of radiator sections.

Fig. 264 will give an idea of this arrangement, this showing a boiler placed in a chamber and some radiators connected up above it. This represents a front view of the chamber, but with the front brickwork, which would come level with the boiler front, removed to expose the interior. The cold supply and expansion pipes are not shown. A chamber of this kind should have access, by a door, for cleaning out dust and brushing the heating surfaces clean. The valves to regulate the radiators can then be inside the chamber.

This method of heating is sometimes adopted for heating the ground floor of a residence, visible radiators being objected to in the rooms on this floor. On the floors above, however, the ordinary radiators are used and heated from this boiler, which stands in the warm air chamber. It will be seen that there is no objection whatever to this arrangement, in fact, taking the general results into consideration, it is a plan that can be commended.

Hood went to great lengths to show what ill effects *might* accrue from warming apartments with air that had been heated by passing over and having contact with the hot iron of cockle stoves. This stove was merely a furnace with an iron exterior or shell, this being encased or surrounded with another shell, the space between the two forming the air chamber, with usual inlet and outlet. This arrangement had two bad features, one being that the air had to have intimate contact with the iron; and secondly, the inner stove was so constructed, that the least want of care in firing made it red-hot. This latter is what has to be particularly guarded against, and were there not stoves devoid of this defect the system would be decidedly faulty. Possibly, the cockle stove used in this way was the cause of the long-lived prejudice against this work, though comparatively few were used to account for it.

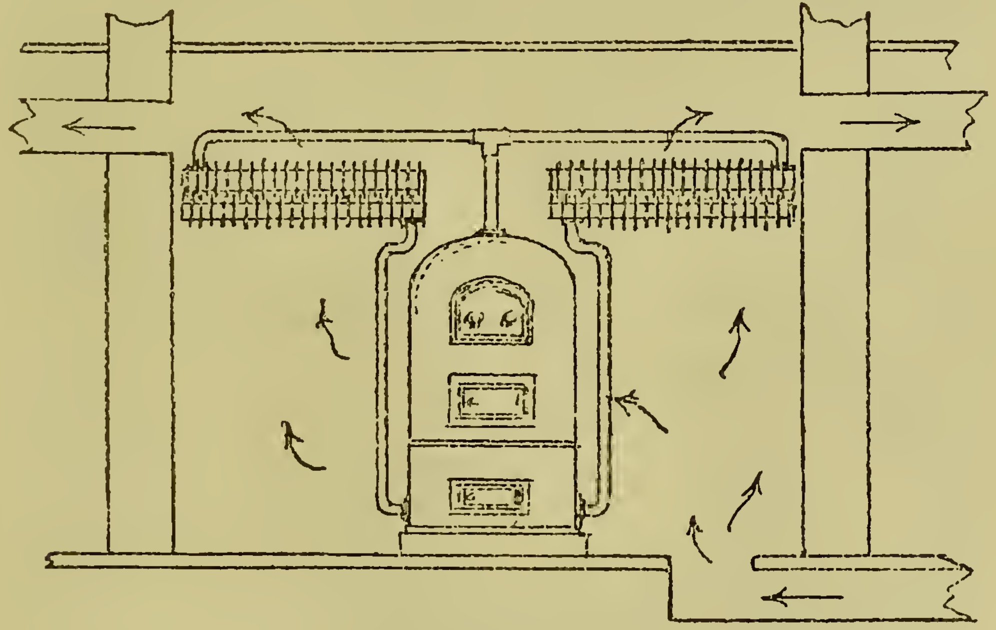

Fig. 264.

Hood recommended a plan, as Fig. 265, which was a decided improvement on the cockle. The stove was lined with fire-clay, to prevent its overheating so easily as its predecessor did, and for warmth to the air the multiplied flue pipe was relied on. This, however, left room for improvement, as the pipes nearest the stove quickly became red, with a deleterious effect.

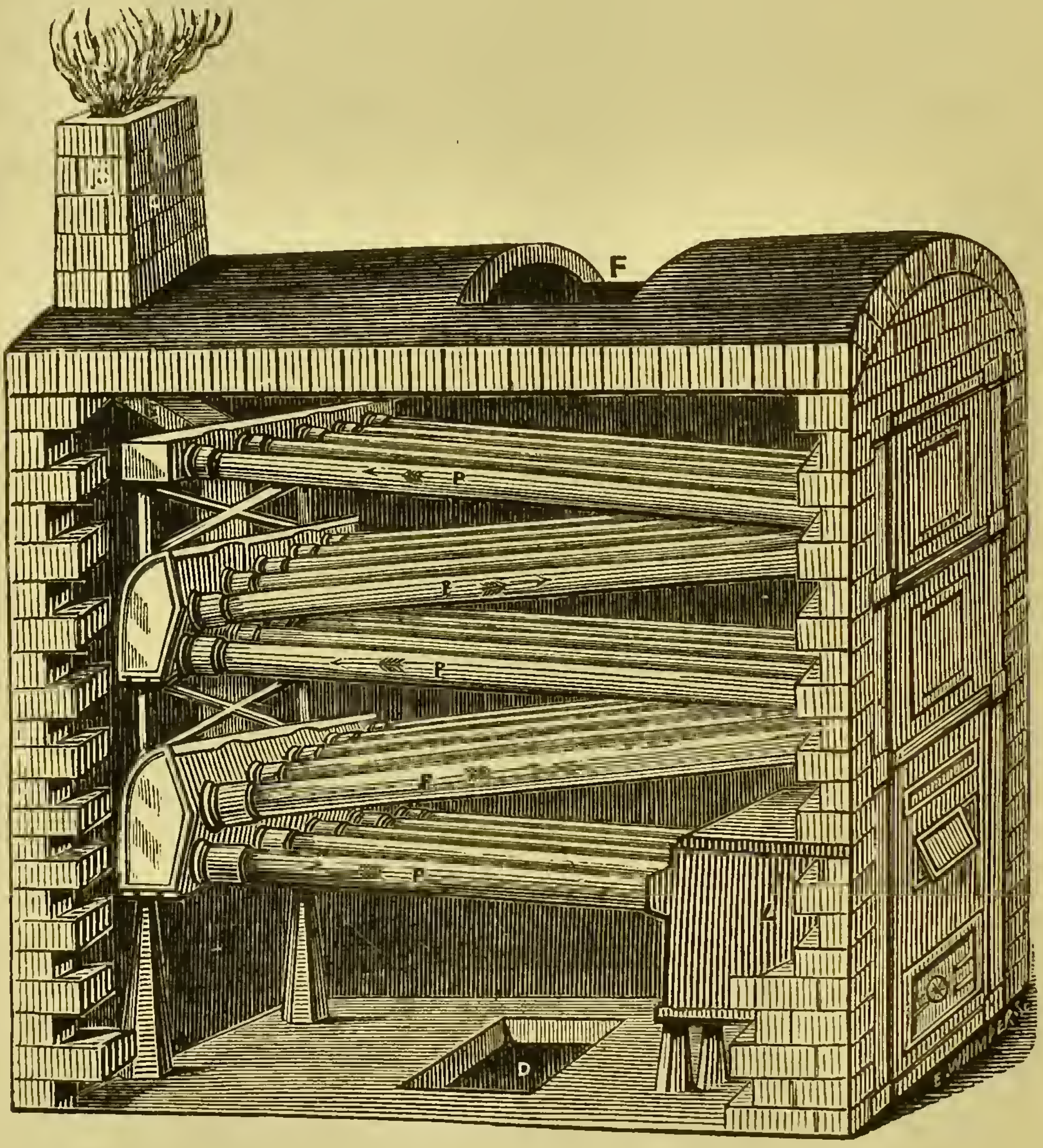

Fig 265.

We have no information at present to show that air, either in its composition or nature, is affected by contact with overheated surfaces of stoves, however high their temperature may be. From all we know at present, the only ill effects are entirely due to insufficient moisture, and vitiation due to particles of organic matter * being decomposed on having contact with the hot plates.

The question of moisture requires full consideration in connection with this subject, for it has to be pointed out that although the vitiation and consequent ill odour might possibly be put up with, we cannot long afford to breathe very dry air without noticeable discomfort, and injury to health in some cases.

The peculiar feature connected with the moistness of the atmosphere, and what causes all the trouble, is, that as we increase the temperature of the air we have to increase its moistness in a regular proportion. Air at outdoor temperature, having a certain and correct percentage of moisture, when warmed becomes dry and unpleasant, not because it has lost any of its mositure, but because it has had none added to it proportionately with its increase of temperature. Table II. in the Appendix shows the proportions at different temperatures, and unless this degree of moistness (or very nearly) is attainable, the warmed air will be, to say the least, unnatural.

This trouble can be remedied somewhat easily by introducing water by some means, so that the air as it absorbs heat can at the same time, or immediately afterwards, pick up moisture. This is commonly and satisfactorily accomplished by placing troughs or pans on or around the stove in the air chamber or some accessible place, or when the warm air conduit is large enough, arrangement is sometimes made to have strips of cloth hanging in it, a species of curtain (not sufficient to arrest or retard the passage of air), this being kept moist from a trough above. If we can efficiently moisten the air, this possible source of trouble with stove-heated air is overcome.

The ill effects which have been alluded to are practically

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* A large proportion of the particles of matter floating in the air, and which we call "dust," is organic material, wool, fibre, volatile substances, &c., readily affected by heat, and producing more or less unpleasant odours and effects.

overcome by using "Gill" stoves, this form of stove having a number of plates, or gills of solid iron, projecting from it. The idea is supposed to have originated with a Mr. Sylvester about 1830, and there is a deal of sense in it. The peculiarity of a gill stove, is that it cannot very well be overheated to an objectionable extent, and although we do not get air at so high a temperature, we get equal ultimate results of a more agreeable nature. The air is obtained at a lower heat, but in a proportionately greater quantity, to produce the same total effect.

The gills on this description of stove answer the useful purpose of increasing the radiating and air-heating surface ; but with this largely increased surface we do not get so high a temperature as we should do with the mere shell of the stove if the gills were absent. If it could be correctly so expressed, we might say that we get the same measure of heat, but with a gill stove less temperature and greater volume, with a cockle higher temperature in less volume. The latter is more objectionable for heating air, from a health point of view, than the former. The reason the gills act as radiating surface, is due to the high conductivity of iron (of which they are composed), the heat being transferred from the interior to the outer limits of the gills with the greatest rapidity desirable.

Fig. 266 shows a gill stove fixed in a brick chamber, this chamber having a fresh air inlet and a warm air outlet, the latter being continued to wherever required. As shown, the stove should be fixed in such a way that all stoking, &c., can be done without in any way interfering with the air chamber. In many instances this chamber is made without any provision for inspecting its interior ; this is a bad practice, as a door, or aperture, can readily be placed for inspection and cleaning. The air chamber should only exceed the size of the stove by from 3 to 6 inches, and the fresh air inlet should be situated and arranged so that the air introduced *must* have contact with the stove, and not escape into the warm air conduit without being heated.

The position of the inlet and outlet for the air requires consideration for another reason, viz. that if the passage of warmed air from the air chamber to the outlets is induced by its less specific gravity only, and is not impelled by mechanical means, it is very necessary that the inlet for cold air be at a low point, and the outlet for warmed air at a high one. Otherwise we shall most probably get a reverse action, as we should with a hot water circulating apparatus, for the acting principle is practically alike in both.

A warm air apparatus exhibits its advantages when discharging the heated air through gratings in the entrance hall of a large residence, for the air distributes itself in all directions from this point, and as the supply is never-ending it is soon felt all up in the house and in the rooms, if the doors be left open. The entrance hall and staircase in a residence have been likened to an artery, and the comparison is good, as by distributing warm air freely in the hall the whole of the house will be benefited. As an instance of this, a good-sized house, having a rather large square entrance hall, was heated by a gill stove, only measuring two feet long (18 gills), placed in an air chamber, as Fig. 266, the warm

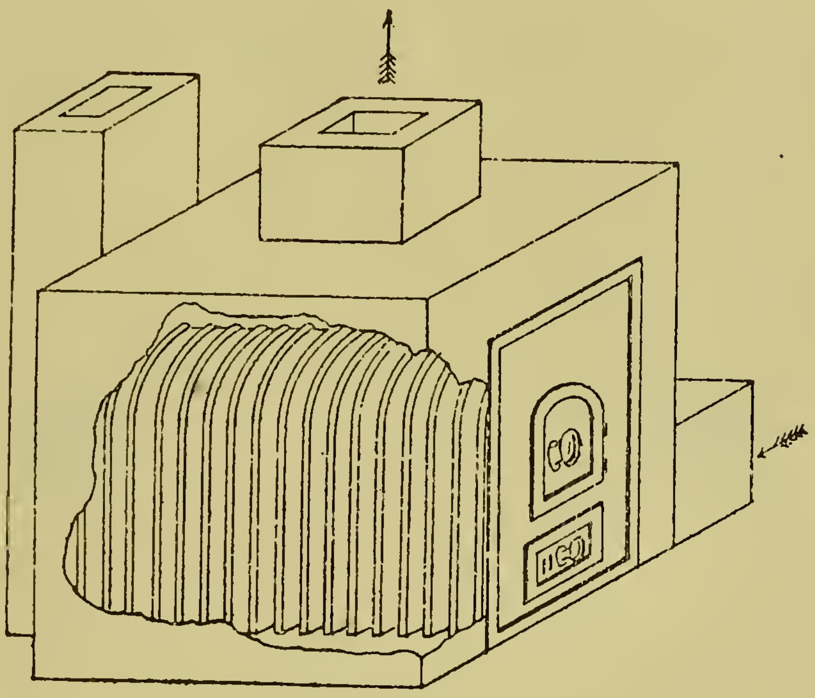

Fig. 266.

air conduit being branched, as Fig. 267, with four gratings in different parts of the hall, the stove being a few feet below. This little apparatus warmed the hall, staircase, landings and corridors all up the house thoroughly, and contributed to no mean extent towards heating the rooms.

There is no doubt that an objection to this system of warming exists in the general difficulty of application and the consequent cost. In a new building provision can readily, and to an extent inexpensively, be made by building brick, or laying earthenware pipe conduits for the warmed air to all the points desired. If provision is made in this way in course of construction a deal of trouble is obviated, and the system is by no means an expensive one, as its construction at this time would very likely be less than a hot water apparatus. Provision for moistening the air must not be omitted.

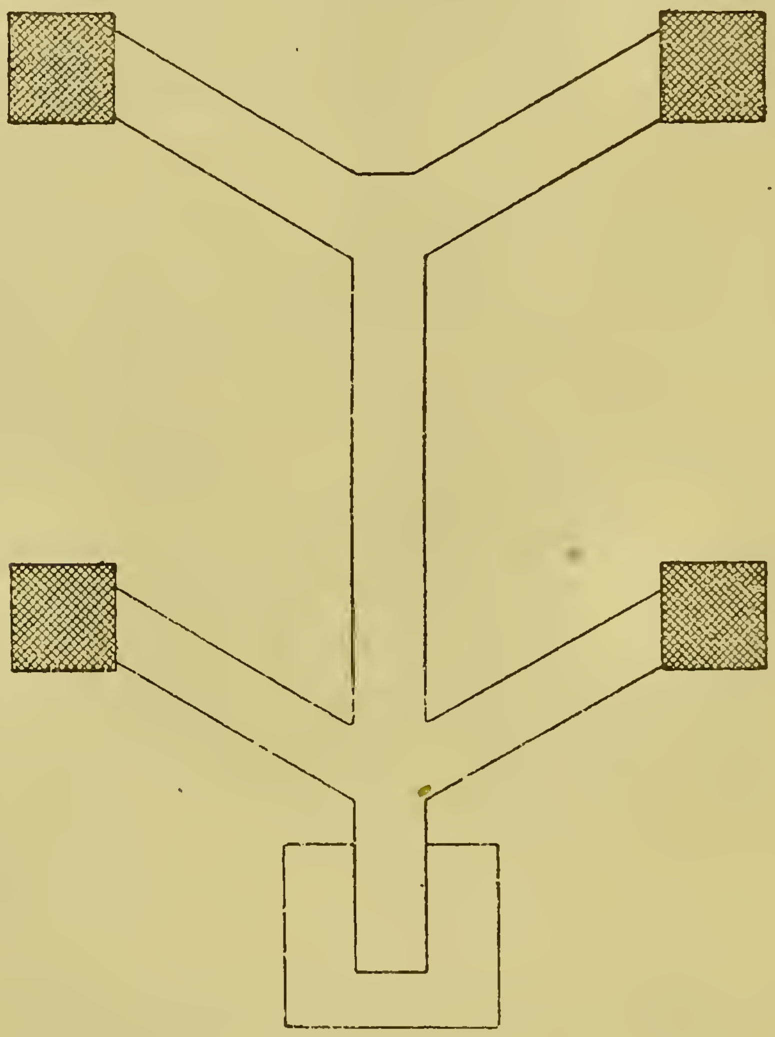

Fig. 267.

In a building already constructed much work would probably become necessary, as it is next to useless having the warm air conduits of small size, and, as they would then have to be of iron, they cannot be carried here and there like small hot water pipes. Both iron and earthenware are used for this purpose, sheet iron most usually on account of its less weight and the less number and strength of supports needed. The sizes of these conduits vary to some extent with the magnitude of the works, but even for small purposes they should not be less than 7 inch diameter, if round, or an equal area if square or any other shape, and for moderate and fair-sized works 7 inch to 9 inch will be required.* It would be hard to err on the side of having too large a pipe, unless these pipes were left uncovered and so could lose heat ; this, however, should not be done, as will be referred to presently.†

With a brick-built air chamber it would be best to continue the warm air conduit in brickwork also, as far as possible, and then let the pipes branch from it ; in that case the brick portion of the conduit would be of larger size. Brickwork, wherever it can be used, is always the best on account of its heat-saving properties, which should be considered an important feature with the warmed air passages, particularly if the free passage of air in the direction required is due to its rarefaction, and not to any mechanical or blowing arrangement. Next to brickwork, earthenware pipes may be considered best, as these lose very little heat compared to iron, but they are cumbersome and introduce a deal of work if suspended.

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* Nine inch is far from being the maximum size ; these sizes only apply to residence works, as for large public building the conduit for some distance is sometimes a passage way in brickwork large enough to be walked through.

† Round pipes are generally used to convey the warmed air to the ground floor rooms, these pipes being suspended from the cellar ceilings below. To convey the warmed air upstairs flat square sheet iron pipes 10 by 4 in. or 12 by $3\frac{1}{2}$ in. can be used, as being less conspicuous. These may be decorated.

With exposed iron pipes we not only lose much heat, representing a loss of fuel and also a slower passage of air due to the decreased temperature, but we introduce a source of danger if the pipe be too near any inflammable material. The latter point, however, is regulated by the Building Acts (see end of book); but at all times iron pipe conduits should be covered, otherwise the loss may cause a failure. An

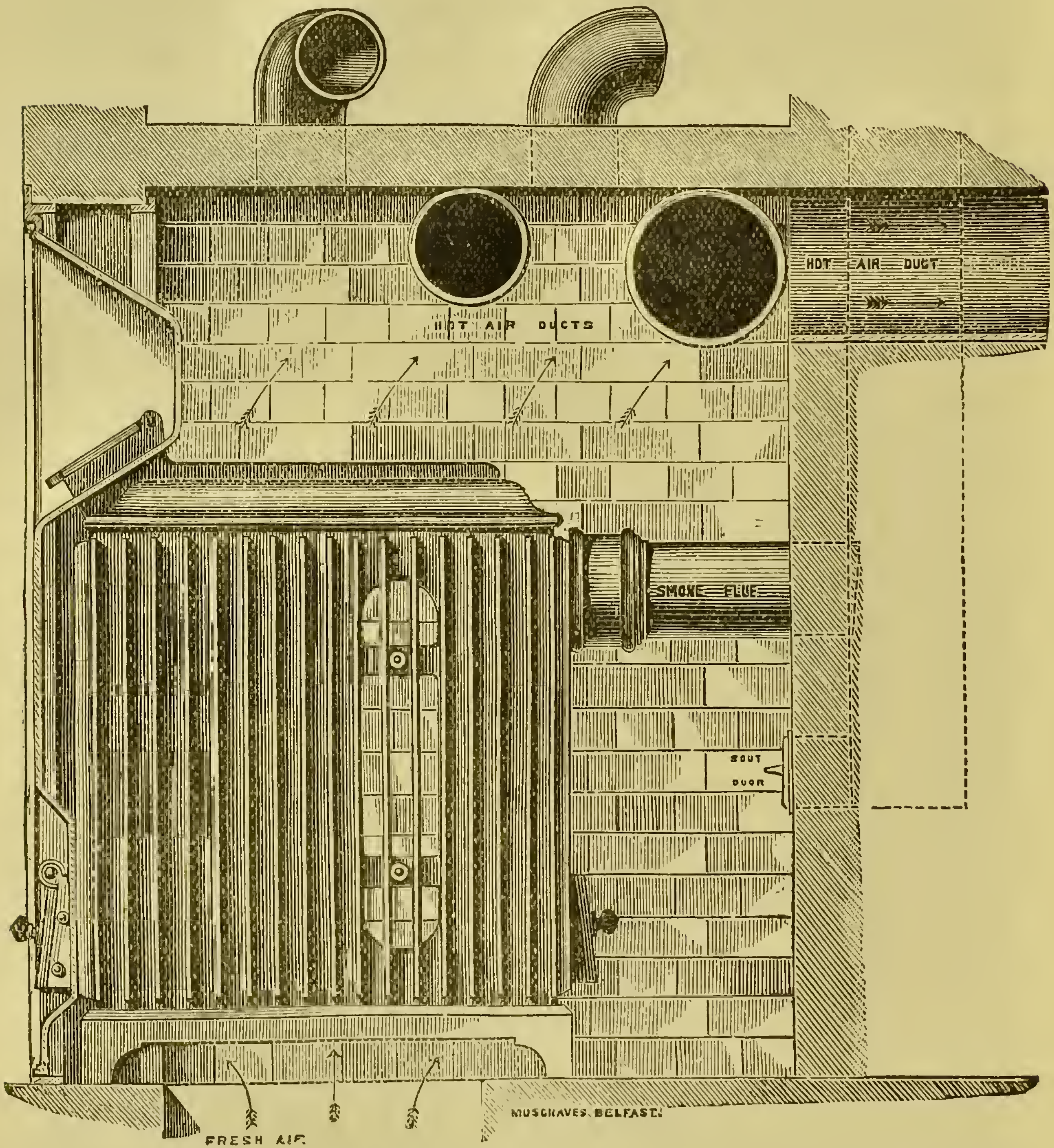

Fig. 268.

excellent material for covering these conduits is silicate cotton, a substance that cannot be too highly commended for this purpose. It can now be obtained in almost any form, either loose, or as a felting from 1 to 6 inches thick, or woven in thick bands, &c., and its price is as low as could be desired.* From recent experiments made this material is found to be nearly as efficacious, as a poor conductor of heat, as animal wool and down, neither of which could be used (apart from their cost) by reason of their inflammability.

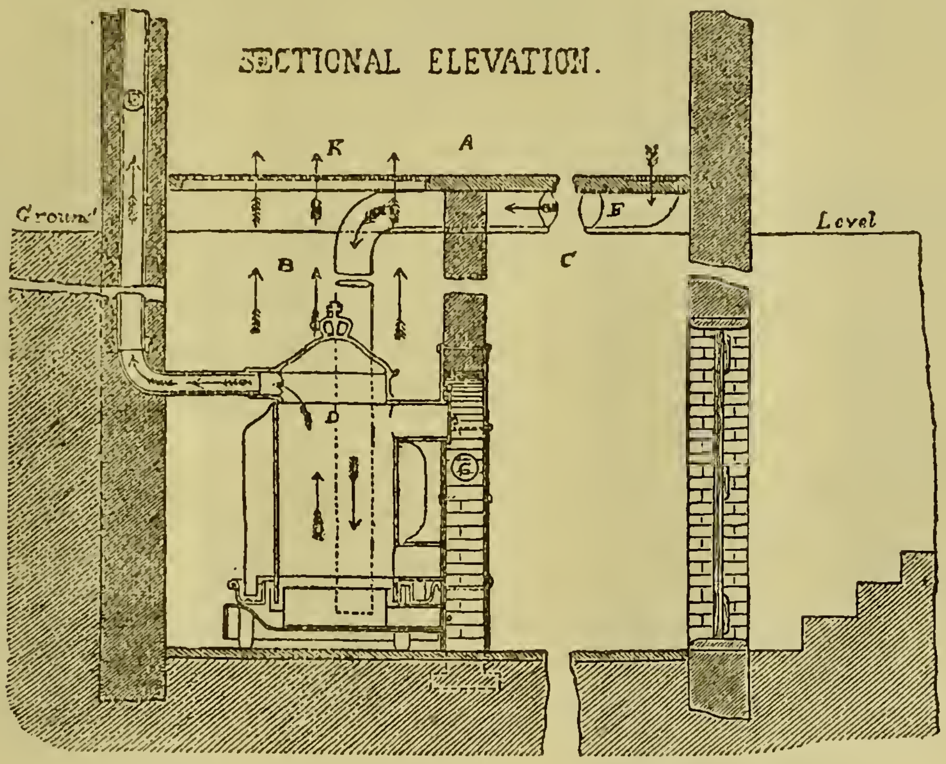

Fig. 269.

A firm who make a speciality of stoves for hot-air works (or for ordinary direct heating) illustrate one arranged as Fig. 268.† This is a gilled stove shown fixed in a brick chamber, the stoking doors coming outside. The earthenware pipe conduits for the warm air are also distinctly shown.

An important feature with all stoves made for this purpose is that they must be constructed to remain smoke-tight at the joints, and there must be no great liability of a fracture that will admit smoke and products of combustion into the air chamber. The junction of the flue pipe with the nozzle of the stove and with the chimney must also be sound, and remain so.

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* Messrs. McNeill & Co., Bunhill Row, London, E.C., furnish this material. The price is 10*s*. 6*d*. per cwt., or 9*l*. per ton. A ton has a covering capacity of about 2000 square feet, one inch thick.

† From the catalogue of Musgrave & Co., New Bond Street, London, W.

Fig. 269 * represents the "Gurney" stove, placed in a vault to warm the air supply of a building. The Gurney stove embraces in a most successful and practical manner the utility of gills or flanges attached to heating surfaces. The stove is circular in form with gills standing out all round its circumference. A very unique feature is in the lower ends of these gills which terminate in a water trough running round the stove to receive them. The object of the water trough is to provide the necessary degree of humidity to the warmed air as already explained, and a more successful plan could hardly be conceived. The stove is here shown discharging warm air through a grating above it.

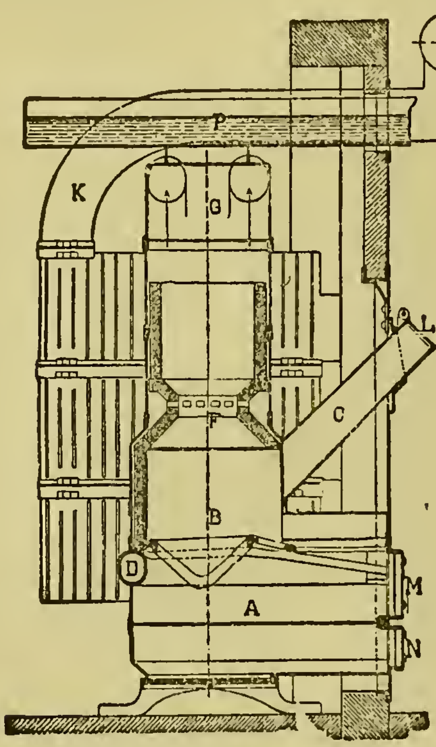

Fig. 270.

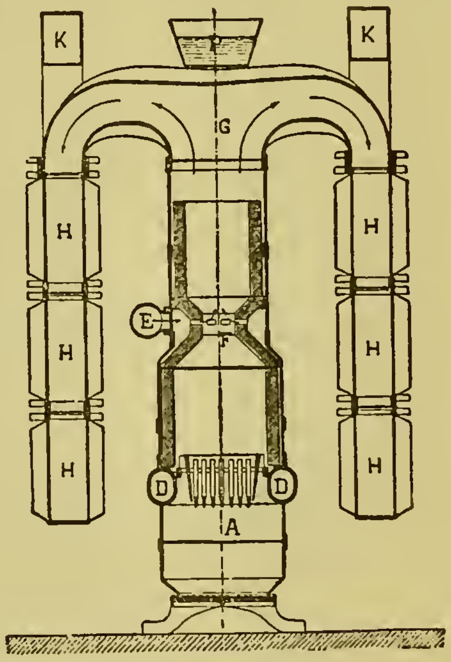

Fig. 271.

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* Made by the London Warming and Ventilating Company, 105 Regent Street, London.

This stove (a battery of them) has the reputation of sucessfully warming St. Paul's Cathedral when all other attempts had failed. The Gurney stove is made for use in exposed positions for ordinary warming purposes, as well as in stove chambers for heated air works. Its sizes vary from 5000 to 120,000 cubic feet, these figures denoting the area a single stove is capable of heating.

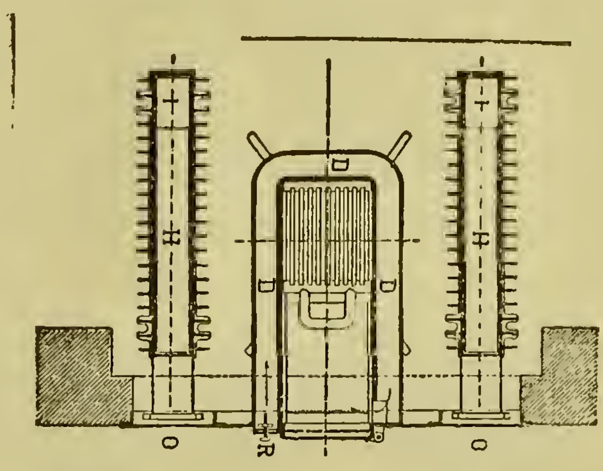

Fig. 272.

Perhaps the most complete appliance for warming air in a central chamber (for distribution by gravity and not mechanically) is Grundy's "Calorifer" smoke-consuming central heating apparatus.* Figs. 270 to 273 illustrate this heater in plan and sections, and the principal parts of the structure are as follows:—A, ashbox; B, firebox with filling neck C; D and E, air channels; F, G, combustion chamber; H, radiators; I, flue division in radiators; K, smoke flues; L, M, N, feeding and ash doors; O, doors for cleaning out radiators; P, evaporating vessel (with indicator).

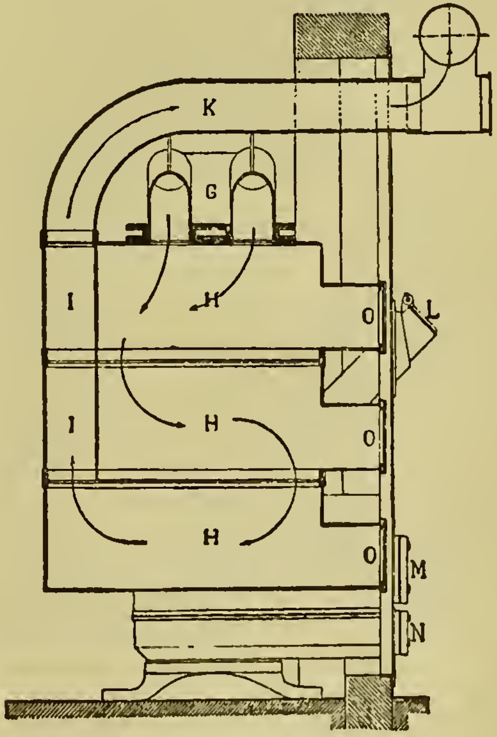

Fig. 273.

The channel D surrounds the grate and is connected with the outer air which is admitted and regulated by means of an adjustable valve. This channel introduces heated air under the grate to ensure perfect combustion. The parts of the filling and combustion chambers most exposed to the fire are lined with fire-bricks, which are cone shaped towards the centre at F so as to form, together with the cast-iron outer partitions, one channel, which is connected with the outer air by E similarly to the channel D. The action of this channel is likewise regulated by means of an adjustable valve. Through this channel highly heated air is brought in contact with the products of combustion to effect ignition of the smoke. Those parts of the combustion chamber which are not lined with fire-bricks have smooth, ribbed or fluted sides according to the heating surface required. On the uppermost casting of the combustion chamber there are four nozzles from which the radiators H are suspended freely (to allow for expansion and contraction). Through these radiators, which are also made smooth or ribbed according to heating surface required, the products of combustion are taken first downwards at H and then upwards again through I to the smoke flues K which are situated on the top. The doors L, M, and N, serve the purpose of feeding the Calorifer, for cleaning out the grate and for removing the ashes. They are made to fit air-tight, and remain closed whilst the apparatus is in action.

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* John Grundy, heating engineer, London and Tyldesley, specialist in this work.

The evaporating trough P is provided to furnish the necessary degree of humidity to the air (see p. 389), and is ingeniously fitted with an indicator, also a means of filling from the front.

The illustrations Figs. 274, 275 and 276 are introduced to show the method of fixing, and the work shown embodies the desirable, and some essential, features requisite when fixing these stoves of any kind.

The illustrations show the heater in an ordinary bricked-in heating chamber located in the basement of a building. The air enters from the outside by the screened window *i* into the fresh air chamber *k*, where any dust carried in with the air can settle down. It is then admitted by a sliding door or throttle valve *m* to the inner fresh air passage *k*, and thence to the heating chamber. These fresh air passages can be entered by an attendant through the door *n*, for the purpose of cleaning out whatever may have been carried in from the outside. Access to the heating chamber proper is by the door *o* to clean the apparatus itself and the heating chamber. This should be done at the beginning of each heating season.

The warm air passes along the ceiling of the heating chamber entering at *b* into the vertical flues leading to the rooms to be heated. Each room has a separate flue, with a warm air inlet, about 6 feet above the floor. The vitiated air is taken off by a separate flue leading above the roof, and having exhaust valves—one a little above the floor for winter

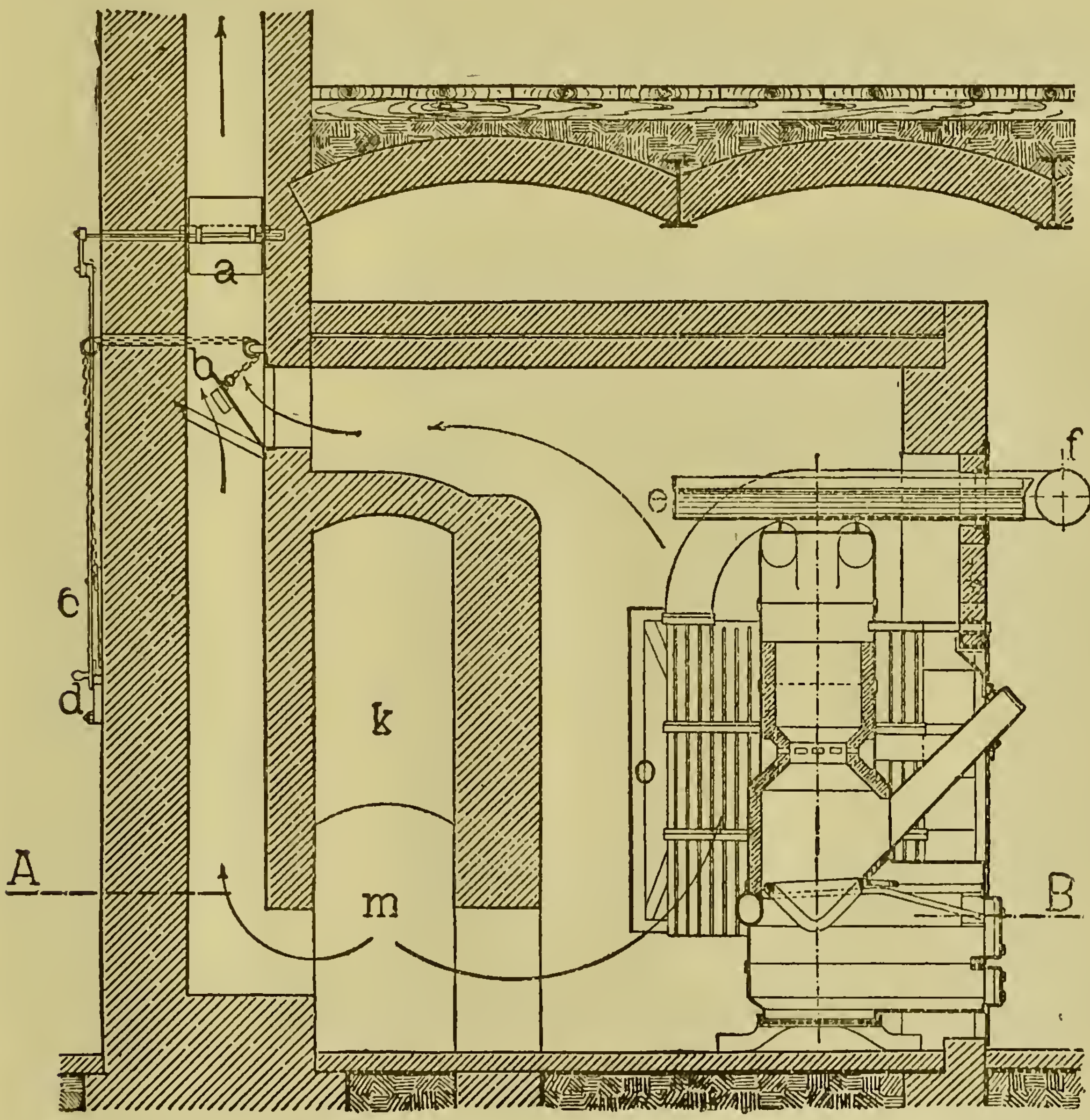

Fig. 274.

ventilation, and another immediately below the ceiling for summer ventilation.*

Although it is possible to regulate the total heat produced in each heating chamber by the quantity of fresh air admitted, yet it is impossible to warm all the rooms equally and ventilate them properly as well, for some rooms being less exposed naturally attain the desired temperature sooner than others. In some rooms the temperature may rise rapidly on account of gas flames or a number of people being assembled, and it is therefore of importance to give each room warm or cold air just as may be required to attain this.

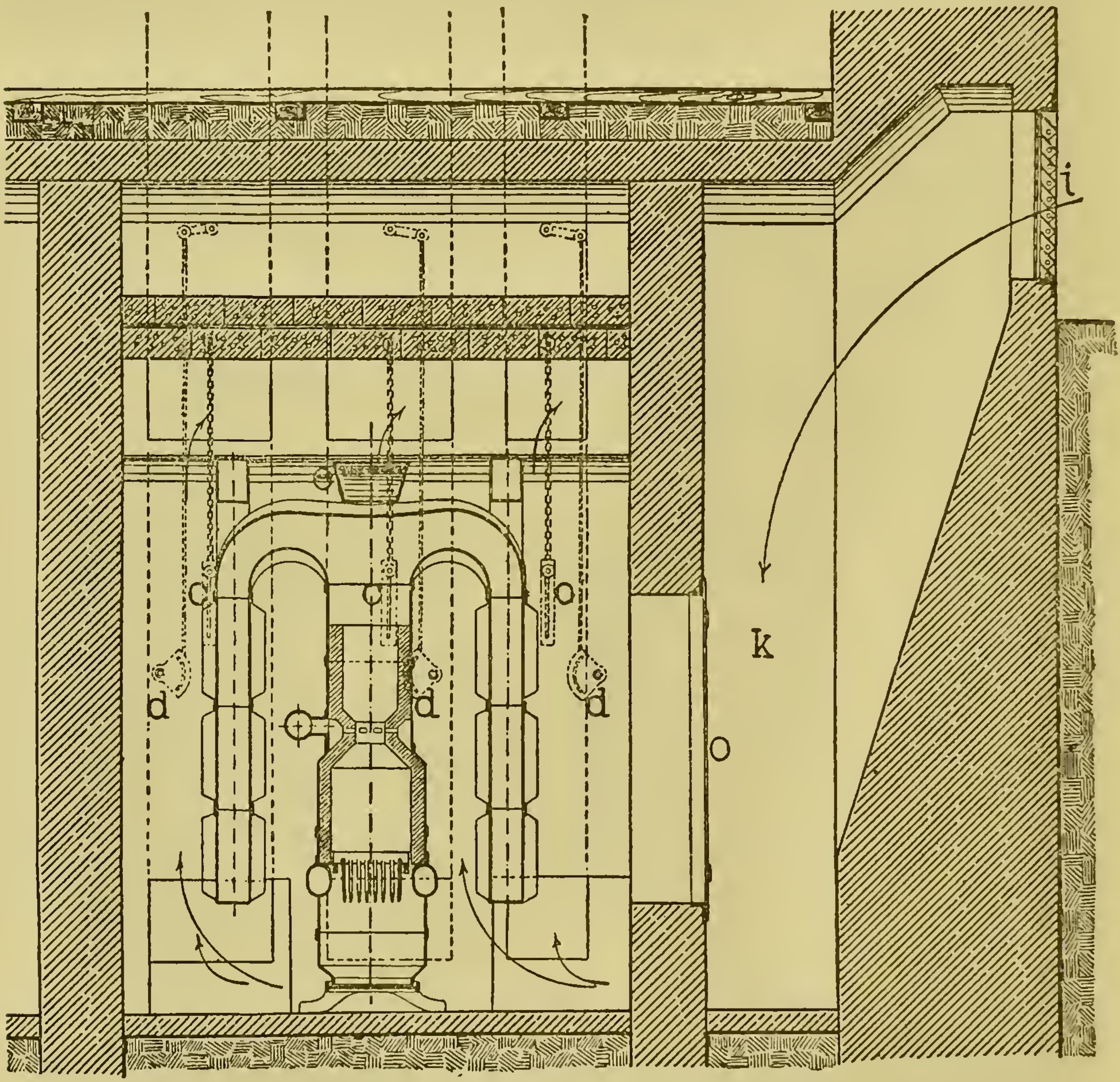

Fig. 275.

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* See Ventilation as to location of inlet and outlet openings.

In each fresh air passage there is a mixing valve *b*, regulated from outside, by which cold and warmed air can be mixed in any proportion, and when the heating begins these mixing valves occupy the position shown in Fig. 274. As

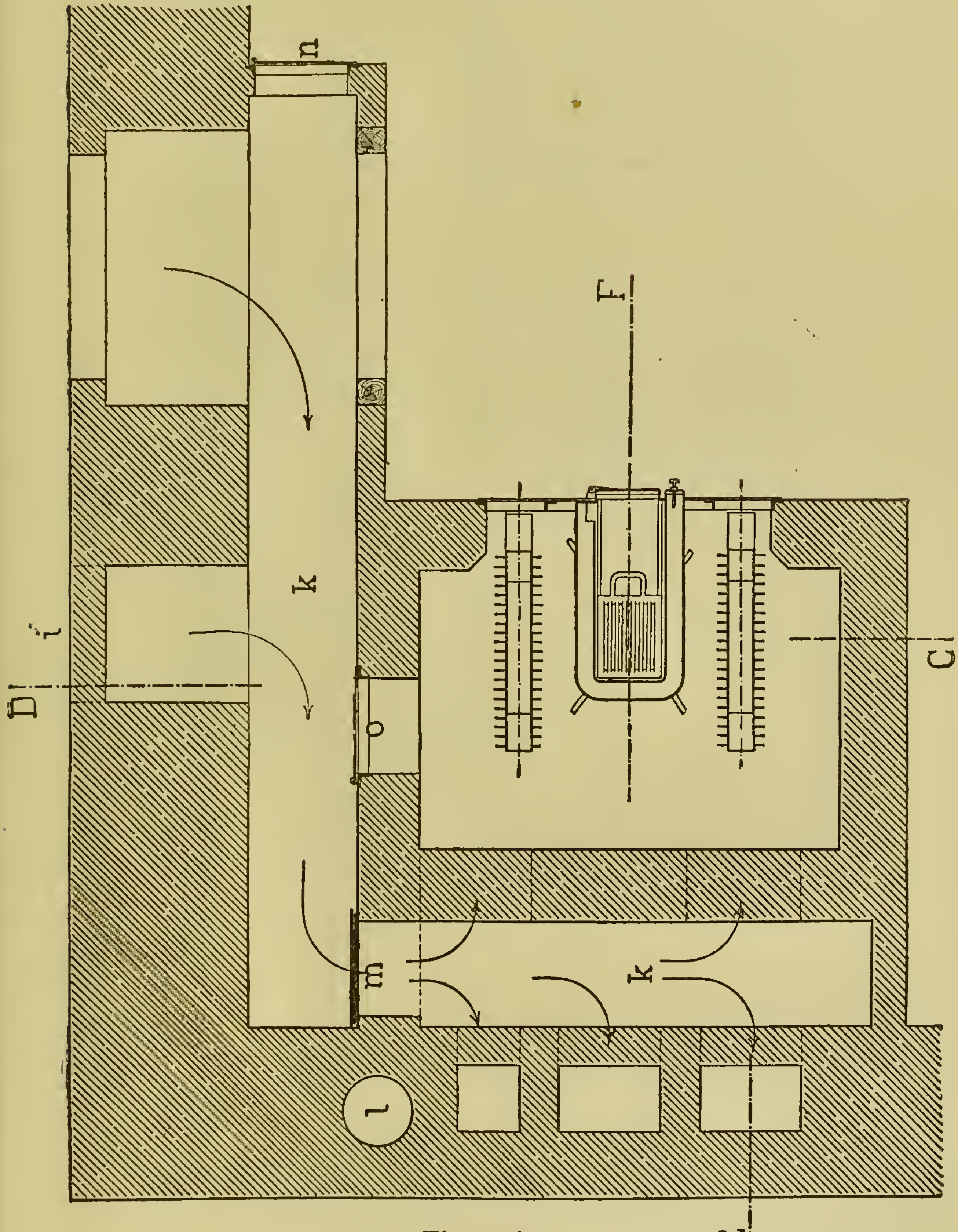
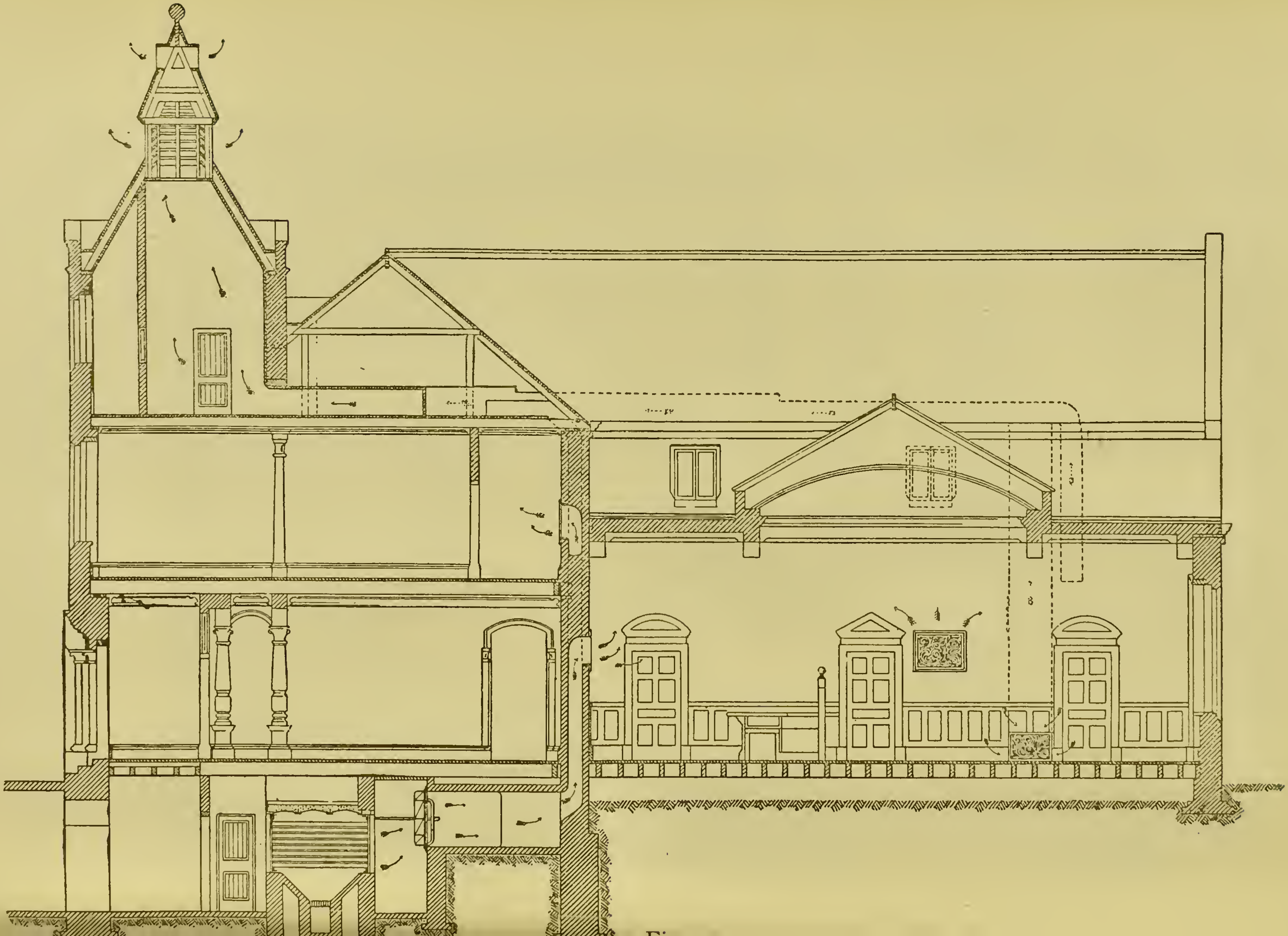


Fig. 276.



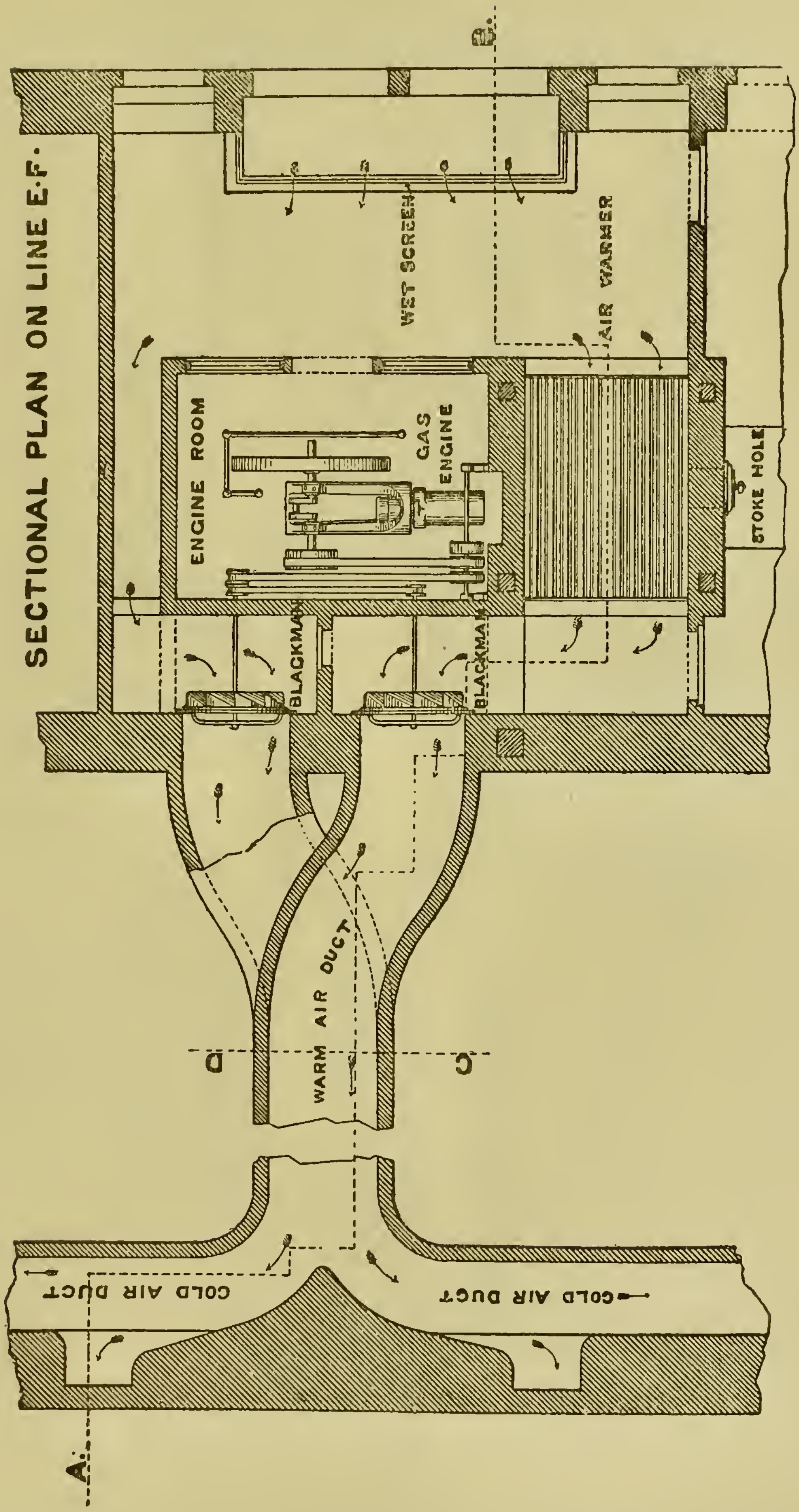
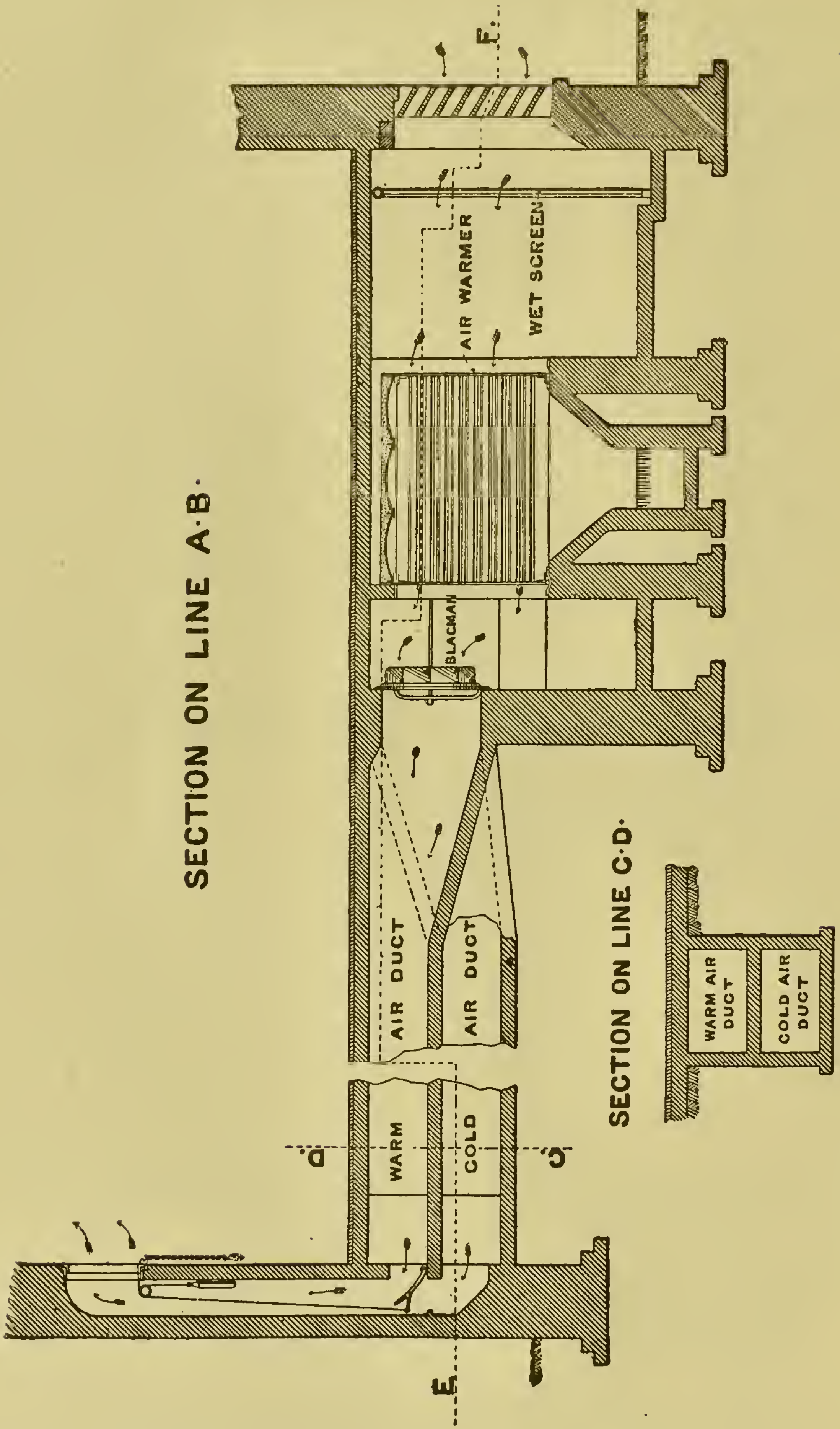

SECTIONAL PLAN ON LINE E·F·
E.
WET SCREEN
AIR WARMER
ENGINE ROOM
GAS ENGINE
STOKE HOLE
BLACKMAN
BLACKMAN
WARM AIR DUCT
D
C
COLD AIR DUCT
COLD AIR DUCT
A.

Fig. 278.


SECTION ON LINE A·B·

SECTION ON LINE C·D·

Fig. 279.

soon as the temperature in any room threatens to rise above the degree desired, the mixing valve *b* is opened, so as to admit sufficient cold air to counterbalance such an excess, and the exact degree desired can thus be obtained and maintained. By means of valve *a* (Fig. 274) a room may be completely cut off from all heating and ventilation.

In Fig. 277 * is illustrated a method adopted for warming buildings by heated air, the air being propelled mechanically; whilst Figs. 278 and 279 illustrate a method acting on the same principle, but with hot and cold air ducts. The latter is entitled the double duct method.

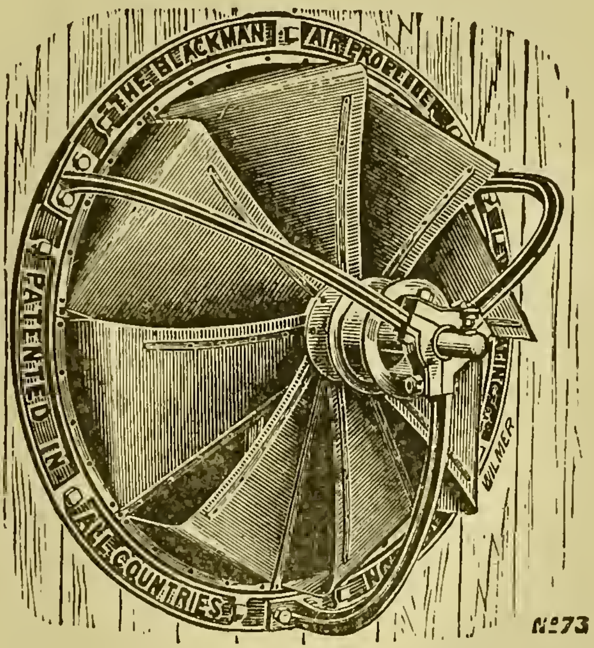


Fig. 280.

In both these it will be seen that the air is driven in by a propeller situated beyond the air heater, but the writer is desired to say that since the illustrations were made the practice has been to propel the air through the warmer, so that the fan is now always placed on the cold air side of the chamber. It will be seen that the object of the double duct method is to admit of a regular volume of air passing in at all times, irrespective of the temperature of the outer air and irrespective of the air warmer being possibly overheated. The mixing valve shown provides for all this, as should the place become too warm it is not necessary to decrease the volume of the air supply, it is only necessary to vary the proportions of hot and cold air a little. Fig. 280 illustrates the propeller used in this firm's works.

In all methods of heating in which ventilation figures at all, great care must be exercised to locate the inlets correctly. The particular care alluded to is to see that the air which enters them is pure and sweet. The writer has seen cases where the fresh air inlet has been in a cellar where the heating chamber had been built, the inlet being merely a hole in the chamber wall. This meant that the air delivered in the house was warmed cellar air, which might be pure, but not desirable nor proper. In other instances the inlets have been placed where odours from stables were obtained ; and one apparatus examined delivered odours of cooking through the warm air registers. Inlets should bring outdoor air to the heating chamber, and this air should be uncontaminated of course.

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* This and the two following illustrations are from the Blackman Ventilating Company, Limited, Fore Street, London, E.C., whose special systems they are.

A wire gauze covering to the inlet opening is commonly thought sufficient, in the way of filtration, to remove solid particles carried in the air, but muslin or a thin layer of cotton wool more perfectly effects this. With these latter, however, the passage of air is materially checked, and the openings should be larger. These materials also require changing at regular periods, the frequency being according to the purity of the air and its freedom from suspended matter, dust, &c. Even a wire gauze screen should be well brushed frequently, although it may not appear to be choked or dirty. In the works last illustrated the wet screen does excellent service as an air filter, besides furnishing the necessary humidity. This screen is kept in a moist state by water trickling over it from a pipe arranged at top.

CHAPTER XXII.

HOT WATER WORKS FOR BATHS, LAVATORIES, AND OTHER DOMESTIC AND GENERAL PURPOSES.

A Series of Papers contributed by the Author to 'The Builder,' and reprinted by permission.

Circulation—Boilers and incrustation—Pipes, taps, and other fittings and appliances—Covering pipes and reservoirs for the conservation of heat—Conversion of a tank apparatus to the cylinder system—Twin boilers and services—Improved and other systems; peculiarities noticed from experiments, and their results in practice—Coils and coil services—Faults and sources of danger—Accidents and sources of danger—Safety valves, &c.—Low pressure boilers, also fitting high pressure boilers for temporary low pressure work.

A SUPPLY of hot water throughout a house is no longer considered a luxury, but merely a common comfort, a necessary, and expected as a matter of course by the majority of tenants of property at as low a rental as 30*l.*

This subject, however, is, of the various trades called into request in house construction, perhaps one of the most difficult for professional men to obtain reliable information upon, owing to several causes; one difficulty being that, as little information has been written or published on this work, knowledge can only be gained by actual experience.

The number of failures that occur in this work is greatly in excess of those in most other trades, by reason of its success or non-success (except in simple every-day jobs) being greatly dependent upon an acquaintance with natural laws, and it is unfortunately obvious that the majority of our mechanics have little knowledge in this direction.

CIRCULATION.

It is but a comparatively short time ago that an attempt to utilise hot water for heating purposes was made by connecting a pipe or series of *single* pipes with a boiler, the hot water (from the boiler) being allowed to run into the pipes. This was found to be a success in a limited way, as the water did not appear to grow cold as might have been anticipated.

The good results obtained were due to the fact that water will circulate in a single pipe, as any one sufficiently interested can quickly determine by experiment, and it will be found that if the pipe be carried in a vertical direction from the boiler there will (supposing heat to be applied) at once set in two distinct movements in the water, that in the centre ascending, and that nearest the surface descending. If the pipe be carried in a slanting direction, the water nearest the top of the pipe will be found travelling from the boiler, and that at the bottom of the pipe towards the boiler.

Possibly, when this attempt was first made it was expected that the heat generated in the boiler would be transferred to and along the water in the pipes by conduction, as would be rightly anticipated if heat were applied to one end of a rod of metal. But as water is an extremely poor conductor of heat the result obtained in the transference of heat from the boiler throughout the length of pipe or pipes was soon ascertained to be from another cause, viz. convection. It is with this property that water possesses that we have to deal, as without it a hot water circulating apparatus could not exist.

The single pipe system was but short-lived, it being almost immediately ascertained that by providing two pipes and connecting them at the extremity, a more rapid and efficient circulation resulted, as it did not necessitate a flow of water in two directions within one pipe. It is from this early arrangement of two pipes that all our systems of hot water circulation for heating and for domestic supply purposes have been developed.

Water is composed of two gases which exist in chemical combination (H_2O) forming molecules, and consists, therefore, of a vast number of extremely minute particles. We might compare water to sand, but it differs from this substance by the fact that water particles have the property of gliding over, under, or around one another (when agitated) practically without the least friction or resistance. Of course water differs from sand also in the fact that we could not have a heap of it, as water, unless confined, instantly distributes itself in all directions; but the comparison is used to make it understood that water is composed of particles or grains (molecules).

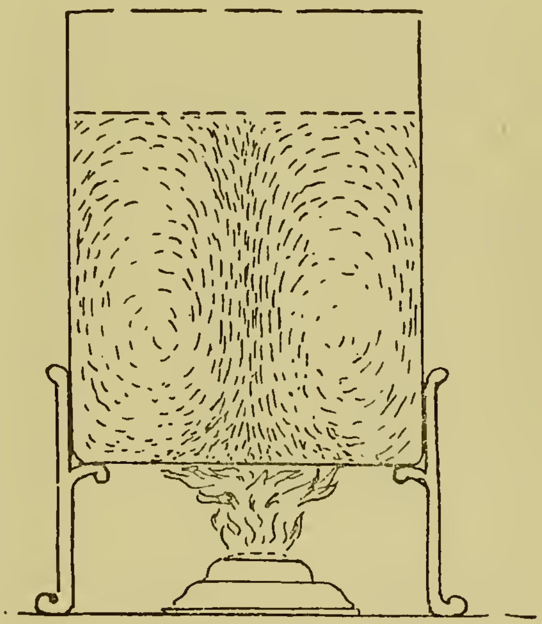

Fig. 281.

When a boiler or vessel is filled with cold water and left undisturbed the particles may be considered to be quite stationary, but immediately heat is applied below, the particles nearest the heated surface become warm, and they, like all other substances, are expanded by the heat. As an expanded particle does not gain in weight as well as size it naturally is made lighter, bulk for bulk, than its fellows.

Immediately, therefore, the particles nearest the heated surface become expanded they are caused to rise by the superior weight of the cold particles surrounding them, and the cold particles that then come in contact with the heated surface become warmed and expanded, and rise also. So the action continues as long as heat is applied; a continuous stream of heated particles rising, and a continuous stream of colder particles replacing them, and this is the process of convection.

When the fire is applied to a boiler having a system of circulating pipes in connection with it, the heated particles rise to the top of the boiler, and finding an opening (pipe) there, continue rising up within it until they reach the highest point in the circulating apparatus. Above this they cannot rise, and it can be readily understood that for every particle that travels up the flow pipe there must be a corresponding particle come down the return pipe to replace it. The action is the same as in the boiler alone; a stream of heated and lightened particles rising until it is impossible for them to rise further, and a corresponding stream of colder particles travelling downwards to replace the heated ones. As they come within the heated area, so they are expanded, and at once reverse their direction, following their predecessors. The circulation proceeds at a much higher speed than is commonly imagined; when first started the heated particles travel about 12 inches per second, and afterwards, when the water is well heated, at about double this rate.

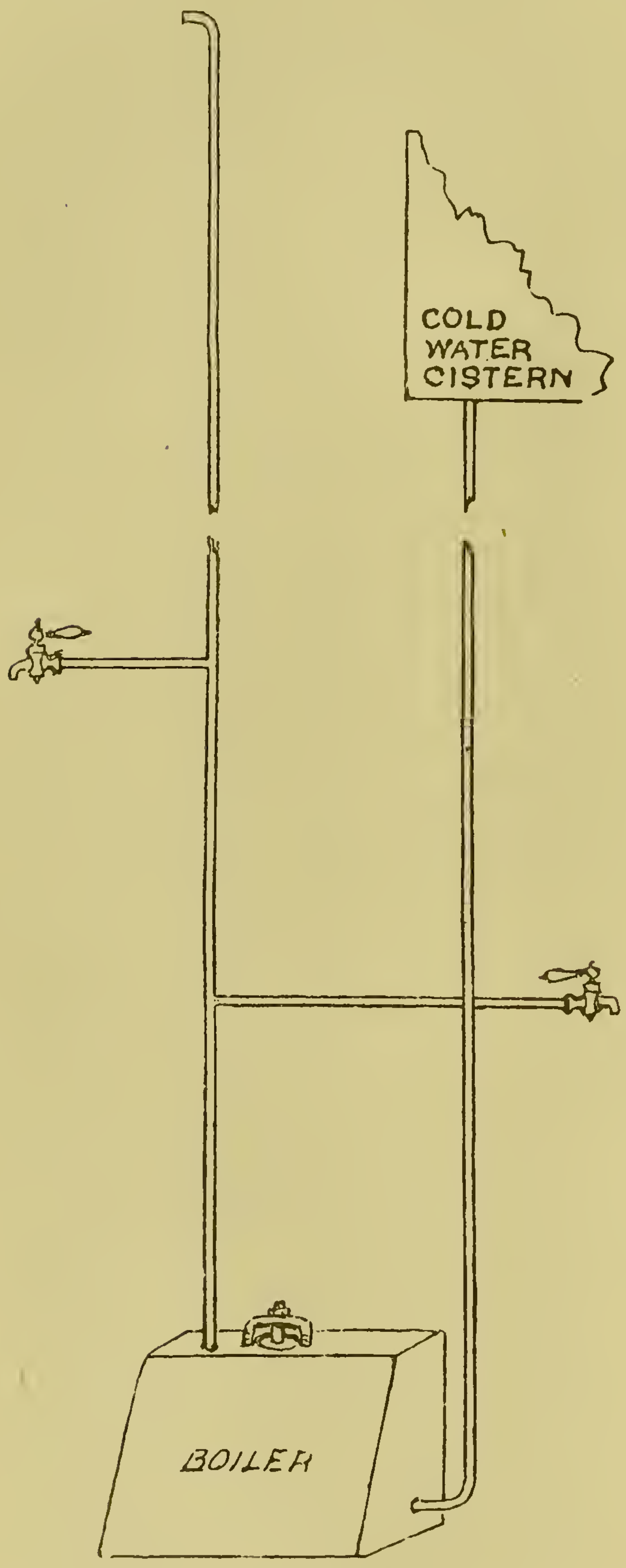

Fig. 282.

The earliest description of pipe apparatus to supply hot water for draw-off purposes above the level of the boiler was merely a large boiler in the kitchen range, a pipe from the house cistern down to the boiler, and a pipe from the boiler to above the level of the house cistern (Fig. 282). From the latter pipe the draw-off services were taken, and it will be readily understood that (water always finding its own level) a draw-off service could be connected and hot water obtained at any point below the level of the house cistern.

There were several insurmountable objections to this arrangement; in the first place, a very large boiler was necessary, as no tank could be used, and the largest boiler in an old open range could hardly exceed sixteen gallons capacity. This was a very insufficient store of hot water, as can be judged by the fact that a tank of such small capacity is not used now for even the smallest of hot water supply purposes. A second objection was that with a long single service pipe a great quantity of cold water had to be drawn off before hot was obtained, and there were several other objections. No doubt, amongst the chief reasons for the discontinuance of this system was the fact that these large boilers were very costly, and as, with the best provision, they were very difficult to clean out, they frequently became fractured, creating no small annoyance and expense. As soon as it was understood that a smaller boiler and smaller fire (with the addition of a tank) would provide a much more reliable and abundant supply of hot water, the old system naturally fell into disuse.

BOILERS AND INCRUSTATION.

Information upon boilers for hot water supply must, to make the subject clearly understood, necessarily be preceded by an inquiry into the cause and effects of the incrusted deposit, or "fur," which accumulates so rapidly in these boilers (when what is known as "hard" water is used), as their shape, construction, and general character is, to a great extent, governed by a consideration of this subject.

The origin of the term "hard" as applied to water holding lime in solution, cannot well be traced; but most probably it was first used in contradistinction to the sensation of softness that is experienced with distilled or rain-water, or nearly any water which has but a small percentage of lime in solution.

Our supply of hard water (practically all of it) may be considered to be limited to that which proceeds either through or from lime or chalk strata, and as this water is usually of a crystal-like clearness, it naturally becomes difficult for the uninformed to make it accountable for the hard stony deposit (limestone, in fact) that incrusts the inner surfaces of these and of steam boilers.

To explain the cause first, the generally accepted theory is as follows :—

Water which descends to the earth in the form of rain comes into contact with, and readily takes up, carbonic acid, either from the air in which this gas is present to a considerable extent in the vicinity of populated places, or from decaying vegetable matter in the open country. This water, charged with carbonic acid gas, percolates through the earth, and immediately it comes in contact with chalk (carbonate of lime, calcic carbonate) the acid enters into combination with the chalk, producing bicarbonate of lime (calcic bicarbonate), which is highly soluble in water; in fact, might also be considered as a fluid itself. It is very necessary to notice this peculiar difference between carbonate and bicarbonate of lime, as it is wholly accountable for the trouble now under discussion. The former, which we speak of as chalk, consists of lime having a certain quantity of carbonic acid gas held in combination with it, and this substance is, as just explained, but sparingly soluble in water. Bicarbonate of lime consists of precisely the same materials, but the quantity of acid gas is exactly doubled, and this renders it highly soluble in water.

It will now be understood that the supply of this hard water is confined to districts where chalk abounds in the soil, and the degree of hardness naturally varies with the nature of the ground. In the south of England, including London and many counties south of London, nearly all the water is more or less hard, but in the north of England the water is of quite a different character, and hard water is, to a great extent, unknown—so much so that large numbers of boilers (for kitchen ranges) are made without manlids or any means of removing any incrusted deposit.

When a new boiler is first charged with this hard water and sufficient heat is applied, the result is to drive off the proportion of acid gas which goes to make the carbonate into bicarbonate of lime. The latter is then transformed into the former again, and, being insoluble, it is precipitated, forming a thin film or coating upon the inner surface of the boiler. This precipitation does not wholly take place immediately heat is applied, but proceeds slowly until boiling takes place and steam is formed, when the chief precipitation is effected. It is almost needless to add that the greatest quantity of deposit is found at that part of the boiler where the greatest heat is felt, but this may be more fully entered into when describing boilers.

The deposit which is effected when using a boiler but once is a very minute quantity, but when we remember that the same water does not stay in the boiler (when the apparatus is at work) more than a few moments, and fresh water is being continually brought to the heated surface by the circulation, we can then understand why the deposit seems to accumulate so rapidly. The heated and (wholly or partially) softened water is being continually drawn off for domestic uses, and entirely fresh takes its place.

This would be a fitting opportunity to explain that with boilers used for heating purposes only, the deposit occasions no trouble whatever, as the same water is used over and over again, and a given quantity of hard water will only yield a certain amount of lime deposit, however long it may be boiled. Of course in a heating apparatus there is a certain loss of water by evaporation from the filling cistern, but this does not usually amount to more than about a quart per week, as the water is not allowed to attain boiling temperature. In a domestic supply apparatus the quantity of water used does not usually come under 400 gallons per week, and in many residences, perhaps, a thousand or more gallons in this time.

The average hardness of London water is about 16 per cent., and a range boiler in regular daily use will have a ½-inch deposit of "fur" within it after six months' use. No rule, however, can be laid down to ascertain at what rate the deposit accumulates, as, although it is easy to find out the degree of hardness of the water, the result is chiefly governed by the efficiency or non-efficiency of the boiler in its heating capabilities, whether the water is nearly always boiling, or whether it seldom reaches this temperature; and again greatly by the quantity of water used, as every drop of fresh water introduced (to replace that drawn from the taps) has its portion of lime to deposit.

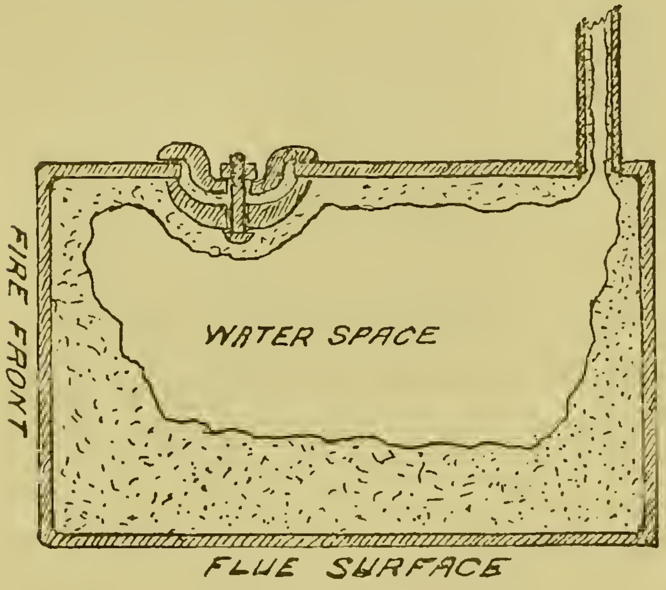

Fig. 283.

In the counties south of London, particularly Sussex, the water is very strongly impregnated with lime, so much so that an ordinary sized boiler will commonly become sufficiently incrusted in from twelve to eighteen months to bring about its fracture. See Fig. 283, which is the section of a boiler badly furred.

The ill effects of this furring consists firstly (and most especially) in its causing the boilers to become fractured before about an eighth of their natural life of service has expired; secondly, a comparatively thin coating of deposit will materially lessen the rapidity with which the water heats, as it is such a poor conductor of heat; and, thirdly, the deposit also locates itself in the pipes, at first retarding the circulation, and eventually causing a stoppage, becoming an element of annoyance, if not danger, unless attended to.

The deposit partakes of a variable degree of hardness or solidity, that which is the most dense causing the boiler to fail the earliest, and that which is most porous permitting the boiler to render the longest service. With the different London waters the deposit is of a variable character, some being very dense and, in many instances, closely resembling ordinary limestone. When this has become of about 1¼ inch in thickness (about two years' use, usually) it is sufficient to prevent the water having any contact with the boiler-plate, with the result that the iron is destroyed by the action of the fire, the same as if the boiler were empty. In instances where the deposit is of a more porous or of a scaly character, it naturally requires a thicker deposit to bring about this result.

The failure of the boiler always shows itself in the form of a small crack or fissure (Fig. 284), not a hole in the common sense of the word. This fissure is rarely larger than 1 inch in length by $\frac{1}{16}$ in breadth, for the simple reason that so soon as the fracture takes place water proceeds from it in a greater or less quantity, and this prevents the fire being ignited. Without the fire, of course, no further damage can be done.

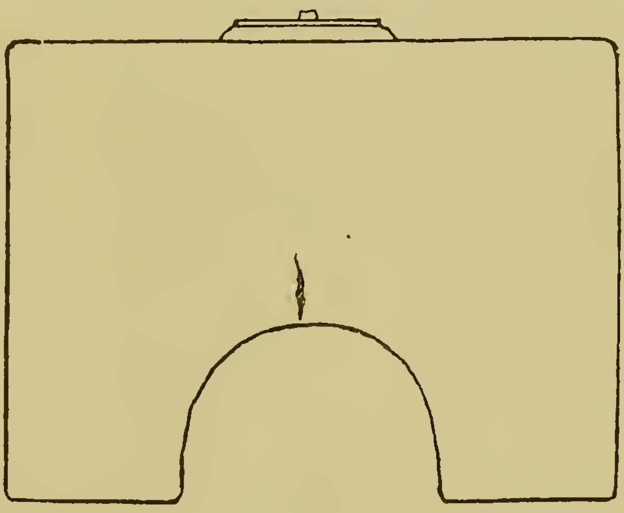

Fig. 284.

There are two remedies for this trouble, one being to soften the water by removing (i.e. precipitating by chemical action) the lime in solution; or, secondly, by having the "fur' removed from the boiler at regular periods.

The first hardly comes within the province of this book, yet it might be mentioned that whatever process is adopted, the softening must be done in a separate cistern, as it would not do to have the precipitated lime carried into the service pipes which run from the house cistern; and each supply of fresh water must be operated upon. It must also be borne in mind that softened water is not agreeable for every purpose, although it may be beneficial to boilers.

The best remedy and the least expensive is to employ a workman to clean out the incrusted deposit at regular periods. This remedy is sometimes a source of inconvenience perhaps, owing to the fact that when the cleaning takes place the kitchen range cannot be used, for, under the most favourable circumstances, this work cannot be done in less than two hours; with some ranges it takes more than a day. The time occupied is to a great extent governed by the amount of trouble experienced in removing the manlid of the boiler. Special means should be provided to make the lid easy of access and removal; but more than three-fourths of the kitchen ranges in the market have no provision of the kind, and the range has to be dismantled and partly unset for the purpose of exposing the boiler manlid.

In "cleaning a boiler," as it is called, the workman has first to get at the lid of the boiler, then to unfasten and remove it; the "fur" is next loosened with a chisel or other suitable instrument—workmen often have some fancy tool of their own for this work—after which it is removed by the hands and the lid repacked and fastened, and whatever parts of the range have been removed, replaced. Of course, the quantity of "fur" that has to be removed will govern the time the work occupies to some extent, but the most troublesome cases seldom take more than two hours after the lid of the boiler is removed.

In London and its suburbs it is found advisable to clean the boilers every six months regularly, in some instances they may be permitted to go twelve months; but it must be borne in mind that the oftener the boiler is cleaned the longer will be its term of life or service, and the less quantity of fuel will be needed to heat the water. A good plan is to have the boiler opened after six months of ordinary use, and a glance will determine whether this period is a proper one for having it cleaned; but in Sussex or in other localities where the water is very hard, the period for first inspection should be reduced to three months. A person about to build or purchase a house in a district of which he has no experience, can always make profitable inquiry from those already resident there. It should be borne in mind that filtration will not remove lime in solution.

The subject of incrustation is being dealt with somewhat fully, as it is a question worthy of every consideration in the south of England. It is no exaggeration whatever to say that seven-eighths, or even more, of the fractured wrought-iron boilers in London (and the number is very large), owe their failure to this cause alone. The trouble is greatly aggravated by the fact that very few of the average householders have any knowledge of the subject. The water gives no evidence of having lime in its composition, and the Water Companies, who are clearly responsible, and who ought to issue information upon the question, are silent. The consumer and user of the water gains experience by paying for it when the boiler cracks.

There are probably from eight to ten thousand pounds sterling spent annually in renewing boilers that have failed from this cause, in the London district alone, and the work is necessarily expensive, as in each and every instance a quite new boiler has to be fitted. It is seldom possible to patch or repair the injured plate ; and to have a new front, the boiler must be made shorter, which, of course, cannot be thought of.

To still further show how prolific of trouble the "fur" is, it might be asked if any one has ever seen a boiler for hot water supply, in the London district, that has failed from actual fair usage, that is to say, really worn out ; it may be taken for granted that very few indeed have ever seen such a thing.

In concluding this subject, it must be explained that the majority of the north of England waters are more or less soft, and differ in character from those of the south in a remarkable degree. The little deposit some of them precipitate is of a muddy nature, which can be flushed out, and it is therefore usual in these districts to provide a pipe expressly for this purpose at the bottom of the boiler. It can be readily understood that different districts must yield waters having a difference in character, but wherever the deposit does not incrust upon the inner surface of the boiler, very little trouble need be anticipated if ordinary care is used.

After exposing the troubles consequent on the use of hard water, it is only fair to point out that it has one advantageous effect upon iron boilers and pipes of considerable importance, viz. that it has a preservative effect and, most important, the water is rarely discoloured with rust. In districts where soft water prevails the rust question has caused almost more annoyance than the "fur" in hard-water districts.

Soft water has a very vigorous chemical action upon both lead and iron, with the result that with iron boilers and pipes the water becomes discoloured by rust to such an extent as to be not only an annoyance but a source of serious trouble. With lead pipes the result is likely to lead to an epidemic of lead poisoning, as it has done many times, and it is on this account that in soft-water districts copper boilers, cylinders, &c., have to be resorted to, but, of course, at considerable expense. The beneficial effect of hard water is in the fact that lime is a strong opponent to the rusting process,* and the thinnest film of carbonate of lime entirely overcomes this trouble. It is on this account that copper, so largely used in the north, is quite the exception in the south for hot water purposes.

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* A most interesting experiment was made at the Royal Institution some years ago with a view to determine whether the presence of carbonic acid in air or water was responsible for the rapid oxidation or rusting that is experienced when iron is exposed to either of these elements in the ordinary way. Two test-tubes were taken and filled with ordinary water, and into each was placed a common sewing-needle ; one tube was sealed up in this state, and the other tube was also sealed after having a small piece of quick-lime (oxide of calcium) placed in it. These tubes were placed away for twelve months, and at the expiration of this time examination showed that the needle in the tube of ordinary water was a mass of rust, whereas the needle in the tube of water with lime in it was perfectly free from rust, bright and equal to new, owing to the lime having taken up the carbonic acid (present in the water) to form carbonate of calcium. This clearly illustrates that hard water has one redeeming feature in connection with hot-water boilers and apparatus.

This peculiarity that lime possesses in opposing the formation of rust can be taken advantage of by coating any form of boiler or iron vessel with lime-white when the vessels in question are inclined to give trouble by discolouring the water with rust. It is a not uncommon occurrence with the ordinary open-top side boilers of kitchen ranges the first month or two they are used ; and more than one cure has been effected to an iron-pipe apparatus, when rusting from the action of soft water, by running a tolerably strong solution of lime-white through it and so coating the interior of all the pipes, &c., with lime. This coating must be allowed to get thoroughly dry before charging the apparatus with water.

BOILERS.

Boilers for hot-water supply, usually called bath or high-pressure boilers, may be divided into two distinct classes, viz. those that are fixed in and heated by the fire of a kitchen-range, and those that are independent.

Neither of these boilers can be made in any great variety of shapes, like those for heating purposes, on account of the "fur" deposit question and all its drawbacks having to be considered. The advantages and disadvantages of some of the shapes commonly seen in kitchen ranges can be profitably discussed, but it will be found that nearly every range-maker, especially if he be a specialist, has a boiler of his own particular pattern, and for which he naturally claims superiority.

There is one object sought by all makers alike, and that is to obtain the largest possible effective heating surface, and so provide a more abundant or rapid supply of hot water than others. This cannot, however, be carried to any great extent, for, in the first place, the boiler is most usually made to the range, not the range to the boiler, and, secondly, the interior of the boiler must be tolerably roomy and clear for cleaning purposes—no tube flues can be permitted, for instance.

If it were not for the trouble that fur occasions, the most efficient and economical form of heater known could be used, viz. a coil of pipe, which, if properly fitted, is all heating surface (ordinary range boilers have a little more than half their surface untouched by the fire); but with London water a coil fixed in this manner becomes furred up and split in eight or nine months. Even with this objection they are sometimes used, their cost not being great, provided their removal and renewal in an expeditious manner can be arranged for.

The most ordinary form of boiler is of a square shape, with a sloping front, and having an arched flue, as at Fig. 285. This is the shape that is almost invariably met with in the cheap makes of ranges—those used by the speculative builder, who considers lowness in cost of primary importance. It is not intended to convey that all boilers of this shape are necessarily attached to cheap ranges, but that it is the shape nearly always used in cheap goods of this sort.

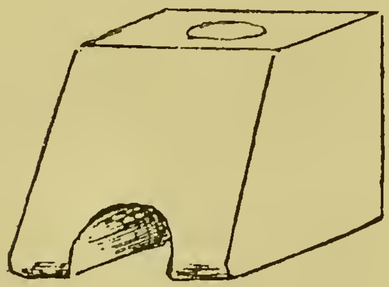

Fig. 285.

This is about the least powerful form of boiler made. They rarely exceed 10 inches in length from front to back, and whatever the object is in making the front sloping it has a most prejudicial effect in decreasing the size of the fire at the bottom, with the result that the accumulation of ash more quickly chokes the boiler flue. The less the body of fire the less brightly it burns with less evolution of heat; in fact, it must have been originally intended to have this front projection at the top instead of at the bottom of the boiler, for this arrangement would certainly be more effective. Any one may perceive that a heating surface overhanging a fire gives better results than one projecting beneath.

This pattern, which is most usually called a saddle boiler, can have its efficiency or heating power increased by adding to its length from front to back, or by adding to its width, so as to give a greater area to the bottom heating surface, but both length and width, particularly the latter, are governed by the construction of the range fire-box.

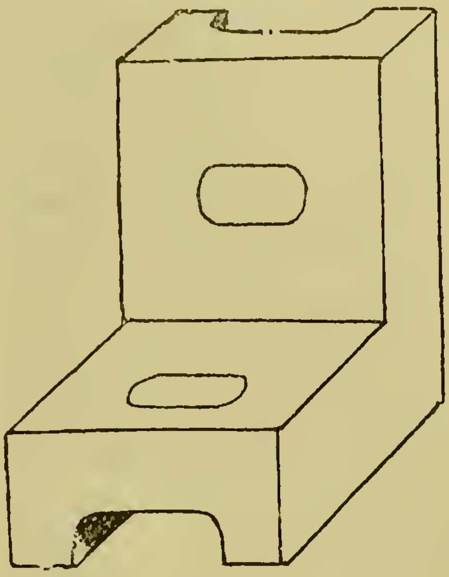

Fig. 286.

The most efficacious way of adding to the power of the saddle boiler, by increasing its heating surface, is to extend it up the back of the range, making it what is known as a "boot" boiler, Fig. 286. Nearly every make of range will permit of this, and the boiler then becomes one of the most powerful that can be used. Such a boiler fitted into a 6-foot range having a 14-inch fire will provide an abundant supply of hot water in a large residence with as many as ten draw-off taps in regular use.

Figs. 287 and 288 * illustrate the most powerful range boilers that are made. In these there is not only an extensive area of effective heating surface, but it is so arranged that the

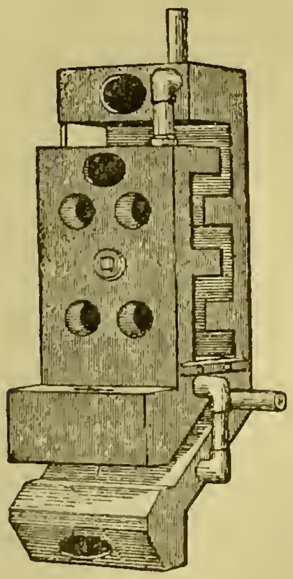

Fig. 287.

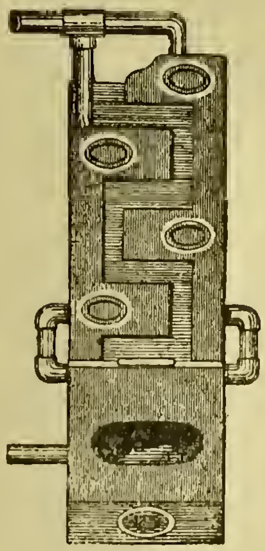

Fig. 288.

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* Potterton's patent "Zig-Zag" range boilers; Thomas Potterton, Cavendish Works, Balham, London, S.W.

flame does not have such a ready exit as from the straight flue of an ordinary boot boiler. These boilers have been designed that their great effectiveness may be utilised for warming the apartments of a house as well as furnishing the domestic hot water supply. As an instance, either design, in a 10-inch fire, is stated to be capable of heating 10,000 cubic feet of space (by hot water radiators) in addition to supplying hot water for the domestic use. Of course, in those instances where abundance of hot water is required, as in restaurants, schools, and institutions, the boiler can be put to do this only and fulfil the purpose effectively.

Another form of boiler to be occasionally met with is similar to Fig. 289, having a tube flue through it, and when made "boot" shaped, the tube flue sometimes continued up the leg portion. This shape has two obvious advantages over the so-called saddle boiler, the first being that the lower part of the flue is heating surface, which is not the case with a saddle, and the flue being raised up from the bottom of the fire prevents it being so quickly choked with ashes. It is commonly considered, however, that these advantages are outweighed by the disadvantage it has in being so difficult to clean out.

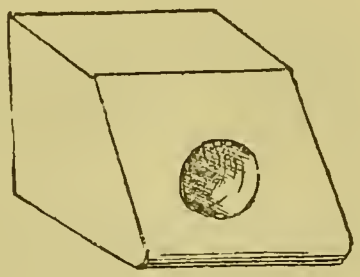
Fig. 289.

Of course it is not an impossible task to clean out a boiler of this description, but it must be borne in mind that this work has to be entrusted to workmen who are no more perfect than those in other trades; and although one man may give additional care to an awkward boiler in cleaning out the front angles—the parts of the boiler needing most attention—another man may be equally careless, with the most unfortunate results.

There is an idea very prevalent that this cleaning process is a simple task that may be relegated to a labourer (fitter's assistant), but no greater mistake could be made. It is work on which an experienced man should always be sent, as particular care must be exercised in removing fur from those parts which are subject to the greatest heat, especially the angles where the welds or joints in the plates exist. Although a boiler is practically a box with an opening in the top, it is worth any one's while to insert his hand in a boiler when an opportunity occurs, to experience what a really awkward and difficult task it is to clean it out, remembering that the "fur" is usually hard like stone, and adhering to the boiler-plate. The trouble is greatly increased by many boilers being turned out with the inner edge of the manhole all rough and jagged with the filaments of iron that always appear on one edge of a hole that has been drilled. There could scarcely be found a single hot water fitter who has not scars upon his arms from this cause.

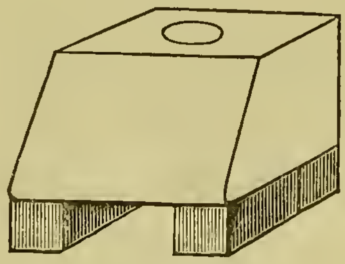

Fig. 290.

There are numbers of people (not range-makers) who signify a preference for square boilers—that is, boilers having a flat bottom without any arched or tubular flue, but which have a flue put to them by being placed on fire-bricks, as Fig. 290. The arguments in favour of these are, firstly, that with an arched-flue boiler a weld or joint has necessarily to be made around the front edge of the arch, whereas in a square boiler a joint need not be there, as the bottom front angle can be formed by simply bending the plate. Secondly, it is contended that the narrow spaces on each side of the arched flue at the bottom of a boiler more quickly get solid with fur. These arguments are considered strong ones by those who use them, but it can be as strongly maintained, firstly, that although a weld does exist in an arched boiler where mentioned, it is not proper for the weld to be weaker than the solid plate. Certainly, boilers when "furred" occasionally open at the weld in question, but this may, to an extent, be evidence of poor welding, for fully three-fourths of the fractures occur as at Fig. 284 (p. 413), in which the crack is shown at right angles to the weld, although close to it. Secondly, the narrow spaces referred to do not get furred so quickly as is commonly argued, and even if they did, a boiler has rarely been known to crack there, and an argument in favour of these side water-spaces is that they add about one-fourth to the available heating surface.

All boiler-makers recommend that boilers to be of good quality should be made of plate not less than $\frac{3}{8}$-inch in thickness. This is certainly a strength that can be used with confidence with the largest boilers for this purpose, including the independent kind; but there is not the least doubt that boilers of $\frac{5}{16}$-inch, or even $\frac{1}{4}$-inch plate, would do a deal of service, if not as much as the $\frac{3}{8}$-inch, for, as already explained, these boilers rarely fail from actual wear. A $\frac{3}{8}$-inch plate boiler will fail almost as quickly as the thinner ones, if the failure is brought about by incrusted deposit. It is not, however, a desirable practice to use boilers of thin plate; the $\frac{3}{8}$-inch is a serviceable and safe substance, and is (or should be) always used in the best quality of range boilers.

The quality of the plate itself is of great importance, but this unfortunately cannot be judged from inspection, not even by the experienced. Good boilers are of the same appearance, and as rough, as those of poor quality, and what might be ascertained from the colour or look of the metal is obviated by the makers coating the boilers with a preservative material, a kind of tar. A remedy for this can be suggested by recommending that such goods be only purchased from good and responsible firms.

No reliable rule can be made as to what size or shape of boiler must be used to meet certain requirements, for in no two residences will the demand for hot water be found to be alike, and supposing the demand did not vary, the manner in which the fire is attended to in the kitchen varies greatly. In fact, the quantity of hot water depends to a very considerable extent upon the amount of cooking done, as it is only when cooking operations are in full swing that the fire is assiduously attended to. It is, however, with every confidence that the "boot" shaped boiler can be recommended; it is decidedly powerful, and although costing more than the saddle shape, it undoubtedly saves its extra cost in the end. It works very economically, and a given quantity of fuel will heat double the quantity of water; in other words, a certain quantity of water will be heated with half the fuel in half the time. Of course, this more expensive shape and size of boiler cannot well be specified for small—i.e. 40*l.* and 50*l.*—property, but where circumstances permit, the boot boiler will well repay the outlay.

Copper boilers, as already explained, are used in a very limited way in the south of England; not but what they are superior to iron in many respects, but for the reason that there is no particular necessity for them, as the chalk in southern waters prevents the rust nuisance so keenly felt in the soft water districts.

One superiority possessed by copper boilers is that this metal being a much better conductor of heat than iron, quicker results are obtained; a second is that the material is of a much more lasting nature, either from the effects of heat or of moisture; but the most peculiar and beneficial result obtained is that the "fur" trouble is, to some extent, overcome.

It is noticed that copper boilers rarely have the deposit incrusted so firmly upon their inner surfaces, a great deal being found lying loose in the bottom of the boiler in flakes or scales. Many causes have been assigned for this, but there is no doubt that the comparatively great expansibility of copper when subjected to heat, and the corresponding great contraction upon cooling, have brought about this effect, the incrusted fur having these properties to but a very trifling extent. The result is the same as would be obtained by covering an elastic substance with a coating of a brittle compound. Of course, copper does not in the least prevent the lime precipitation taking place with hard water, and consequently the precipitated matter, whether fast or loose, has to be periodically removed. The nature of copper is also such that supposing the fur adhered to it as it does in iron boilers, the plates would not become fractured nearly so quickly; in fact, it is much more difficult to do copper any great injury by the heat generated in a kitchen-range fire.

Copper boilers are much more costly than iron; the price is constantly fluctuating, but they commonly cost from four to five times as much as iron of good quality, but it should be borne in mind that a copper boiler, when its longest life of service has expired, is still valuable, whereas an iron boiler when unfit for use is quite valueless.

These boilers are usually made of $\frac{1}{4}$-inch or $\frac{5}{16}$-inch plate, excepting the front, which should be thickened to $\frac{3}{8}$-inch or $\frac{1}{2}$-inch, not so much to withstand the action of the fire as to bear misdirected blows of the poker, as copper is soft and rather easily penetrated. Sometimes a slab of cast iron is made to place in front of the boiler, this slab being of exactly the same shape as the boiler front with the arched flue way at the bottom.

When ordering copper boilers it is very necessary to have brass strengthening bosses or rings brazed in where the pipes are connected, unless the plate is of good thickness, otherwise difficulty may be experienced in making a thoroughly rigid joint when inserting the unions. And the rim of the manhole should be similarly strengthened or still greater trouble will be occasioned in securing the manlid. It is also necessary to order the manhole of good size, as makers are apt to send out these boilers with not larger than a 3-inch manhole, tapped and screwed to take a 3-inch brass screw plug which does duty for a lid. This arrangement may suffice in soft-water districts (which nearly all copper boilers are ordered for), but for the removal of incrusted deposit the workmen would not be able to get more than their fingers through the hole, and a manhole might as well be omitted if the whole hand and arm cannot be passed through.

A fairly important feature in a boiler is the manlid itself, which is provided to securely close the manhole. These lids have considerable variety, both in shape and size, but in general character or construction the majority of them are similar to Fig. 291 (shown in section). This consists of a circular or oval lid seen at the top of the illustration, and a "bridge" which is shown below it; the pin through the centre with nut at the top securing the two. This is the usual style, but occasionally an inside lid is met with, which merely consists of a nearly plain casting secured by two set-screws passed through the boiler-plate. This is a very simple device, and, if anything, preferable to the outside lid, which occupies space unnecessarily; and it will be readily seen that the pressure of water within the boiler tends to make the lid more secure rather than to cause it to leak.

A form of manlid to be objected to, unless a very large hole has to be covered, is that which consists of a plain wrought plate secured by a number of set-screws. In the first place, the wrought plate is easily made uneven by the least improper or careless usage; secondly, great care is needed in making the packing material equal in substance all round the hole, and the set-screws have to be most carefully screwed up to effect a sound joint. A still further objection of some importance is that the screws sometimes rust in holes and break in when an effort is made to remove them.

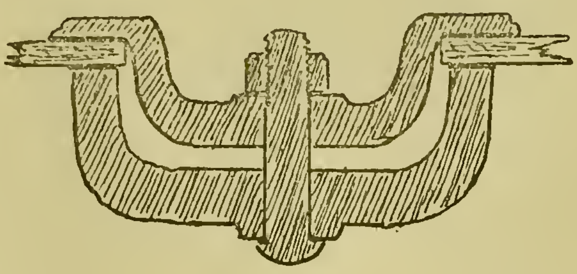
Fig. 291.

Whatever form of manlid is used, its object is, of course, to stop up the manhole of the boiler in a thoroughly sound manner, as these boilers are often required to bear very high pressures (the inner surface of a manlid often has a pressure of 500 lbs. upon it, i.e. 25 lbs. to the square inch); and as boilers and manlids are not made with such perfectly true surfaces that they will fit together in a water-tight manner, a jointing material has to be used between the surfaces. This jointing usually consists of hemp, with a mixture of red and white lead of the consistence of putty. This material has been used almost from the time boilers were first thought of, yet for general purposes nothing has superseded it to any noteworthy extent. The hemp is sometimes used in strands and sometimes chopped up and incorporated with the red and white lead mixture, but better than the hemp in hanks is a material called "gaskin," which is a soft, thick, cord-like substance. The particular advantage gained by using a cord is that dependence can be placed in making an even joint; with loose hemp a perfectly even joint is almost impossible.

A material now largely used by the majority of workmen and which answers very well, for the joints rarely fail, is ordinary cardboard of a moderate thickness. This the workmen obtain by breaking up a cardboard box or any other cardboard article, and the only preparation needed is to first cut a collar of it to fit the manlid, then soak it well in plain water; if only thin cardboard is obtainable two thicknesses are used; a mixture of red and white lead has to be applied with this. Sheet asbestos can now be obtained made expressly for this purpose, and it answers exceedingly well, but a little objection is that it has to be used in the form of collars. These must either be made to order or cut with considerable waste, but the material itself answers admirably.

There is one other material deserving of special mention, viz. india-rubber, as it has several advantages peculiar to itself. This material is used in the form of collars or washers, several sizes of which can be found in stock at india-rubber warehouses and frequently at ironmongers. There is not such a difficulty in getting a size to fit with rubber as with asbestos, for the reason that any size can be stretched a little, if it is small or irregular, to the shape required, and, if necessity demands it, a circular collar can be made to fit around an oval lid; these collars should not fit loosely if it can be avoided. This material makes manlid packing a simple task, as it needs no preparation, no jointing composition, and it does not taint or render the water impure. The red and white lead joint often has the latter effect, especially when a little too much material is used and squeezed into the boiler as the lid is tightened up. If care is exercised a rubber collar can frequently be used a second time, and to effect this the surface of the collar that comes in contact with the boiler-plate should be blackleaded to prevent its adhering (there is no objection to its adhering to the lid). This material also has its disadvantage, arising however mainly from careless or ignorant work on the part of the hot water fitter. If the fitter screws his flow pipe through the top of the boiler so that it projects to the least extent inside the boiler (as will be more fully explained later), or if he takes this pipe into the side of the boiler, it will to some extent cause a steam chamber to be formed close to the top surface of the boiler. As steam will not protect india-rubber from the action of fire heat, it will fuse or melt, and in perhaps not more than two or three hours after lighting the fire. Rubber collars are also very troublesome where there is a liability of water running short, as immediately they are subjected to a little higher temperature than boiling water they fuse. Notwithstanding this they are to be highly recommended, as their disadvantages are only apparent when bad work or dangerous circumstances exist. An inside manlid with a rubber collar is as near perfection as we have arrived at yet.

INDEPENDENT BOILERS.

It is only quite recently that the importance of using independent boilers for hot water supply has come to the front, the chief reason being that residences even of large size were considered complete in their hot water arrangements if a supply was provided to a bath, lavatory, pantry, scullery, and housemaid's closet, and a good sized kitchen range will furnish these with an abundant supply (or should do). The desirability of having hot water services conveniently situated for every practicable purpose is now receiving much attention by professional men, tradesmen, and clients, and unfortunately a good many failures are being experienced, as it naturally does not readily occur to one's mind that the kitchen-range boiler is going to fail in the useful work it has done for so many years.

An instance occurred quite recently in which a 6-foot range with a boot boiler of the largest possible size that could be fitted to such a range, failed most signally, for investigation showed that the cylinder (hot water reservoir) was a very full size, viz. 100 gallons, the pipes were a very full size, being 1½ inch throughout; there were thirteen draw-off services, including three baths, and two taps in the stables, which have a great demand for hot water; also a butler's sink, which when three-fourths full held about sixteen gallons. In addition the hall was heated by two radiators, and a linen-closet heated by a coil—all from the kitchen-range boiler. The result made one believe that the boiler would not try to do the work, as the constant demand gave the boiler no opportunity to heat up a store of water. The introduction of an independent boiler of medium size entirely remedied this, as these heaters are very powerful and very rapid in results.

It is intended to treat the question of radiators and coils somewhat fully when the time arrives, but it may be mentioned here that these articles greatly oppose the efficient working of a hot water supply apparatus, as of course they are made expressly to rob the hot water of its heat by dissipating or diffusing it, whereas with a supply apparatus it is most desirable to conserve every particle of heat within the pipes so that it may issue with the water from the taps.

Independent boilers have very many advantages, and wherever an opportunity to use them occurs they can be most strongly recommended. In the first place they have the important advantage of requiring very little attention in use, and the fire can be kept in for several hours with once feeding, so that water of a high temperature can be had at any hour in the night or early morning. This advantage alone is of the utmost value, preventing, for instance, the annoyance arising from the bath water not being hot in the morning owing to the servants rising at irregular hours. And should there be any heating coils in connection with the boiler these continue to give off heat when most needed, during the cold hours of early morning—a special advantage if there is a small conservatory heated from it.

Small conservatories are often heated from the kitchen-range boiler, but cannot be at all successful, owing to the kitchen fire being out when the heat is most needed, viz. in the night and early morning.

Another advantage, often overlooked, gained by the use of an independent boiler, is the fact that a kitchen range working without a boiler and one working with a boiler give very different results indeed. A range without a boiler at the back of the fire works with nearly double the efficiency, rapidity, and general good results of one with a boiler, and the difference in consumption of fuel is most obvious; a 5-foot range with a high-pressure boiler costs as much in fuel as a 5-foot range without a boiler, but with a moderate-sized independent boiler. Further than this, the boiler fire can be urged independently of the range, and the cooking operations need not be regulated with any consideration for the water supply. Independent boilers can be fixed in any position where convenient for stoking—in a basement or cellar, or at the side of the kitchen range, and the smoke pipe can be connected into the kitchen-range flue. If a vertical shaped boiler is selected, it will occupy but little room, and take a charge of fuel to last all night.

Independent boilers can be had in every conceivable design and size, but there is only one made as yet that is worthy of any particular recommendation for this work. There are great numbers of excellent boilers, so far as their ability to heat water is concerned, but hitherto they have hardly ever been used for other than heating purposes only, manufacturers not having been called upon to consider the "fur" question. This is the drawback to the existing patterns, as there is but one which will admit of easy cleaning.

Fig. 292 represents in section a vertical domed top cylindrical boiler, one occupying little space, and having every convenience for stoking, &c. But a circular boiler of this make is most difficult to clean out, and it should have at least two manholes and three or even four mudholes (holes, about 1½ inch), at the lowest point for scraping out the loose "fur," as the hand cannot be inserted. This illustration shows a boiler having the water-way terminating at a level with the fire-bars, and although the vertical shape of the boiler is good, this lower termination of water-way is a serious defect.

It has been explained that the lime deposit from hard water is precipitated, and consequently collects on any flat or low places that it settles on as it falls. With this boiler the whole collection occurs at the base of the water-way level with the furnace bars, and as the greatest heat is felt here, the deposit causes the greatest possible injury to occur to the boiler plate. It could not collect at a worse point, and the intense heat just at that part causes it to become very hard and difficult of removal.

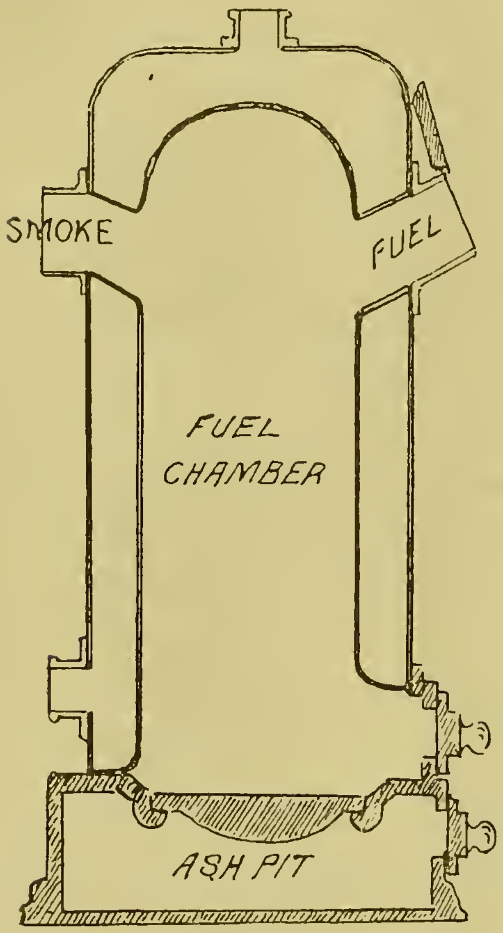

Fig. 292.

For domestic supply purposes, the vertical shape is good, as stated, and the lower part of the water-way has its defect remedied by being carried down past the fire-bars, as Fig. 293. This makes the boiler as perfect as any we have at present, and with ordinary care it will do excellent service. The deposit is precipitated down past the area of intense heat, and where it can do little or no injury. It is also noticeable that the deposit does not incrust in this chamber below the bars, but occurs more as a muddy sediment. This chamber can be cleaned out from one manhole, a far easier task than having to clean round the cylindrical shell. There is, however, a point in this boiler at which the deposit will adhere and incrust, and from which it must be removed regularly to prevent injury. This is immediately over the fire-door, and this point must not on any account be neglected.

This kind of boiler is now to be had in square horizontal form, as Fig. 294. This does not show the water-way carried below the level of the fire-bars, as it is considered unnecessary with straight water-ways which can be easily cleaned. It is, however, very desirable to carry the water-ways down, even if they do not extend right underneath as in the last example. The horizontal shape is not so convenient for receiving a charge of fuel to last the night.

The fuel used with these boilers is usually coke, an economical and clean fuel, and if the boiler is filled up to the top the charge is sufficient to last a number of hours, varying with the size of the boiler and the way the dampers are set or regulated. The speed of combustion is regulated by a valve at the furnace front, and it can be further regulated by having a flue damper fitted in the smoke nozzle or pipe. The coke fuel must be broken small, about walnut size, otherwise it will wedge or "bridge," and the fire burn hollow by reason of the fresh fuel not falling as the lower portion of the charge is burnt away.

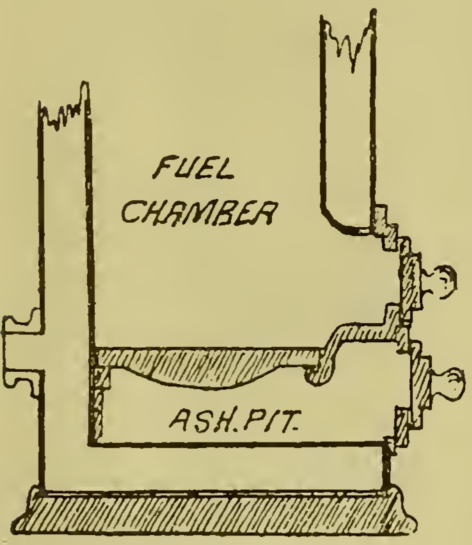

Fig. 293.

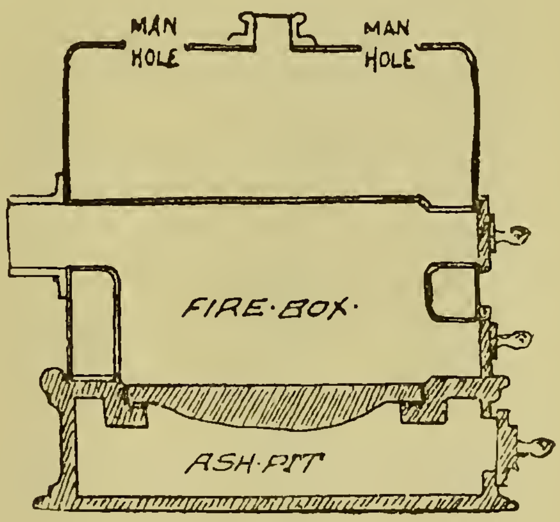

Fig. 294.

In ordering an independent boiler the following information is required before the maker can proceed :—State the position that the smoke nozzle is required in, whether on top or whether projecting from the back or either side (the furnace and stoking doors are always situated in front). State what size water pipe is being used, and state where the return pipe is to be connected (the flow pipe should always start from the top). Indicate where the manlids should be put, so as to be easily accessible for removal. State whether $\frac{5}{16}$-inch or $\frac{3}{8}$-inch plate is required (the latter is about one-fifth more expensive than the former, and it is much the better to mention that a slide damper is required to go on the smoke nozzle, as makers do not provide this unless specially ordered.

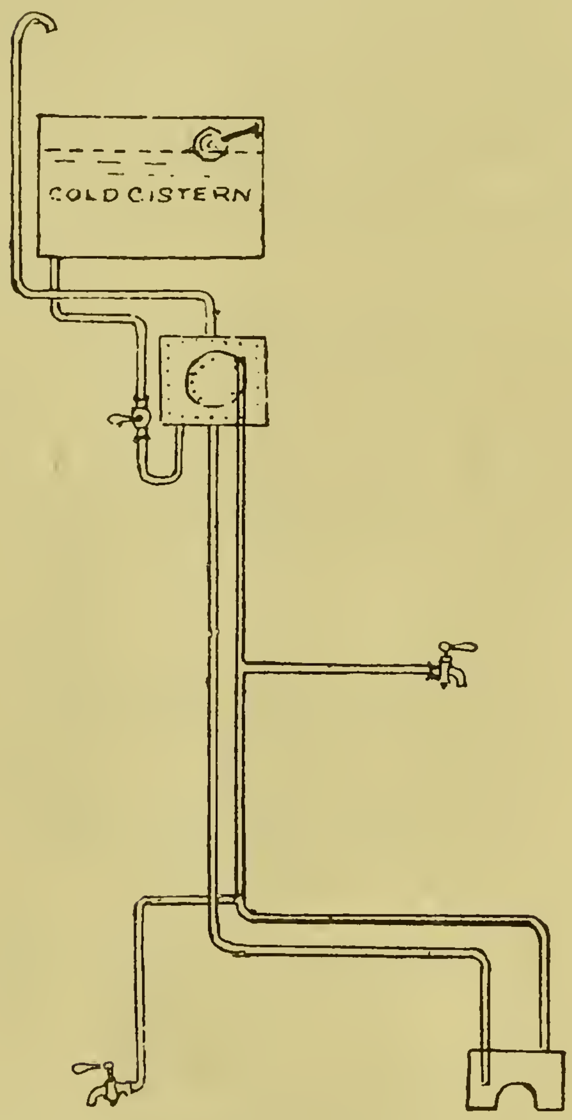

Fig. 295.

Before proceeding to treat the various fittings, tanks, pipes, &c., used in this work, it will perhaps be best to describe the two most common forms of apparatus in general use, as by this means the explanation devoted to appliances will be rendered more clear.

THE TANK SYSTEM.

This is the style of apparatus that succeeded the simple arrangement described on p. 410, Fig. 282. Strange to say, it has never had any distinguishing name given it, and the term, "tank system," is only now applied to distinguish it from the cylinder system which follows.

Fig. 295 is the general arrangement of this system, and one of the chief features about it, as the name implies, is the tank, which is always fixed, somewhere above the highest draw-off service. This is commonly in the bath-room, or an up-stairs linen closet, or in the roof. If the tank is fixed anywhere below the draw-off services, it practically converts the apparatus into the cylinder system, as will be understood directly.

As to the position of the tank, this needs some consideration; in the first place it must be below the cold water cistern; occasionally it is fixed on a level with this cistern, but in principle this is bad and should be avoided, as the least shortness in the cold water supply interferes with the hot water. What is worse, fixing the tank on a level with the cold water cistern means necessarily that it is placed in a cold position, in the roof or in the cistern room. This is one of the objections to this system of apparatus, viz. that the tank being at the top of the building must be in a cold situation. The efficiency of a hot water supply apparatus is in ratio with the amount of heat it can keep within the water, not the amount of heat it can dissipate, or be robbed of by cold surroundings, which is the aim and object of a *heating* apparatus.

To make this system at all economical as well as sucecssful, the tank must be kept warm, or in a warm position. This can be done either by having the tank within a closet or in a warm room, or much better by casing and packing it with some poor conductor of heat—sawdust, hair, &c. The protection of tanks, pipes, &c., is fully treated on pp. 462 to 468.

When the position of the tank is located, a service pipe, known as a "flow" pipe, is carried from the highest point in the boiler to the tank, where it is connected near to the top, either through the side, or through the bottom and projecting up inside, as shown in the illustration. This is the pipe up which the water finds its way from the boiler immediately heat is applied to it. To allow of the corresponding volume of cold water coming down to replace the hot, a second pipe, called the "return" pipe, is provided, starting from a low position in the tank, either from the bottom, as illustrated, or from a low point in the side, and from there it is carried down to near the bottom of the boiler, usually through the top, projecting down inside as shown. It should be noted that it is customary to speak of the "flow" pipe as proceeding from the boiler to the tank, and the "return" pipe as proceeding from tank to boiler.

The flow pipe should always be connected from the very highest point in the boiler, and on no account must it be screwed through the boiler plate, so that it projects down inside in the least degree, otherwise an air chamber will be formed. It will be readily understood that if this pipe project through the top plate, as in Fig. 296, the boiler cannot be filled beyond the end of this pipe, as shown, as the air cannot be expelled. As an example, supposing an ordinary glass tumbler had a hole drilled in its side, and the tumbler was then inverted and lowered into a vessel of water. The result would be that the tumbler would have the water rise up within it as far as the top edge of the hole, but no further (only so far as a certain compression of the air would allow), and the air in the upper portion of the glass cannot be expelled except by having another hole made at the top (or by shaking the glass violently). This formation of an air chamber in the boiler is a very prolific source of trouble, and it occurs with the greatest frequency either through carelessness or ignorance on the fitter's part. It frequently happens that the fitter connects the flow pipe into the side of the boiler, one of the worst of practices, and only to be tolerated under some very special circumstance. When this is done the air is got out of the top of the boiler by packing the manlid, but only partially securing it, so that when water is allowed to run into the boiler, the air is driven out and the lid then finally tightened up.

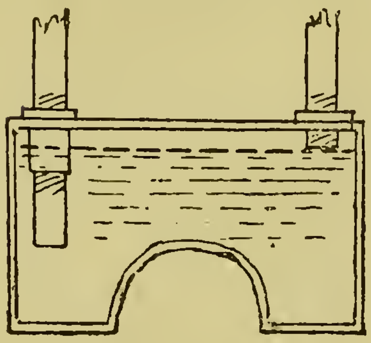

Fig. 296.

The particular ill results experienced from the cause under discussion are that it is accountable for the violent noises and vibrations sometimes experienced with new work (noises in old work are generally accounted for by furred pipes), for when the boiler is heated and steam generated the latter expels the air, and afterwards the steam itself has to escape. As both the steam and the air have to be forced down through water to escape up the flow pipe, the violence exhibited cannot be wondered at. A further annoyance and source of trouble arising from this cause, and which is quite as objectionable as the noises, is the fact that as the water is not always in contact with the upper boiler plate, the manlid packing quickly gets destroyed and wants renewing, and this particularly with india-rubber manlid collars.

The flow pipe, as already said, is taken from the highest point in the boiler, and it is continued from there to the tank and connected between half and three-fourths the way up it. This pipe should nowhere be permitted to travel in a downward direction; if possible, it should be kept gently rising all the way, but sometimes this is impossible, and the pipes that are not fixed vertically have to be carried quite horizontally along passages, beneath floors, &c. There is no positive objection to the pipes being carried horizontally, though it sometimes occasions a check to the circulation, and it is always best if possible to have the pipe rise more or less in every part of its length, if ever so little.

There are some conflicting notions as to whereabouts in the tank the flow pipe should enter. All are of opinion, of course, that it should be somewhere above the return pipe; but beyond this there is no universally agreed position. Some contend that the flow should be immediately above the return, with not more than a 3-inch space between the two; others consider it should enter at least three-fourths the way up the tank; and there are various other opinions on the subject. There is not the least doubt that the flow pipe should terminate between half and three-fourths the way up the tank, for, in the first place, we have to remember that if the quantity of hot water be ever so small, it will be found in the upper half of the tank (when once it has had time to reach the top of the house). Secondly, and more important, all the draw-off services are taken from this pipe, and as water proceeds both up and down the flow pipe when a tap is opened (as will be shown more fully presently), it would be bad policy to have the upper extremity of the flow pipe anywhere near the bottom of the tank where the cold water enters. It is sometimes thought that having the flow pipe entering near the top of the tank (as just recommended) lessens the quantity of hot water at demand. This idea, however, is erroneous, for it will be seen that, supposing the tank to be three parts full of hot water (the upper three parts, as a matter of course), when a tap is opened, the hot water commences to flow down the flow pipe, and as fast as it does so an equal quantity of cold water enters the bottom of the tank from the cold water cistern. The cold water as it enters lifts the hot water up above it (as the cold and hot do not mix readily) and no cold water will issue from the tap until all the hot has passed out. If the contents of a tank could be watched at this time, it would be found that no noticeable mixing of the hot and cold waters took place, but the quantity of the hot water would be seen gradually growing less at the top of the tank, and the bulk of cold water growing greater and greater, but creeping up from the bottom.

All draw-off services are taken from this flow pipe, and it is usual to arrange the apparatus in the best way to avoid long draw-off services, as a long draw-off service means annoyance by having to draw a quantity of cold water (from the hot water tap) before any hot is obtained. The annoyance is particularly felt at lavatory basins, which usually have small, slow-running taps, and it is not at all uncommon to meet with instances where a lavatory tap will have cold water issue from it for half a minute after being opened, before any hot is obtained. This is a serious objection in another way, as every drop of cold water that flows from a hot water tap has been heated once, but allowed to get cold for no useful purpose, and no apparatus of this sort ought to admit of a portion of its heat being wasted in this way.

It can easily be understood that the water in a long draw-off service remains stationary when the tap is closed, and hot water that is allowed to remain so quickly loses its heat and grows cool. When the tap is next applied to for hot water this which has cooled in the pipe has to be run off before the hot water issues. Then when the tap is closed the pipe is again left full of hot water only to grow cool before the tap is opened the next time, and it is by no means uncommon for a single draw-off service on an ill-devised apparatus to waste as much as twenty gallons of hot water per day by this means. This waste of heated water has often been largely accountable for the failure of an apparatus, the waste actually exceeding the quantity of water used.

The usual remedy, when a long draw-off service must necessarily exist, is to "return" it. This is effected by continuing the service pipe back to where it started from, but connecting it to the return pipe, as Fig. 297. This will permit the hot water to circulate up to a point near to the tap, and the annoyance is supposed to be at an end. Such an arrangement, however, as successful as it may be in bringing the heated water to the vicinity of the tap, fails when the tap is opened. It is very important to consider what happens in these works when a tap is turned on, and in this case it will be found that the issuing water proceeds about equally, half from the flow pipe which is hot; half from the return pipe which is usually cold. This cannot, therefore, be considered a practical arrangement, although it is most widely practised everywhere. When the fault is recognised it is sought to minimise it by putting this branch return in small pipe, as a rapid circulation is not needed, but this is only a partial remedy. A better plan is to put a "check" (stop-back) valve in the return of this draw-off service; this will permit of the circulation occurring, but on opening a tap the water proceeds from the flow pipe only. What may be considered the correct plan is to make a branch flow pipe of the draw-off service, starting from the main flow as illustrated, and returning into the same pipe a

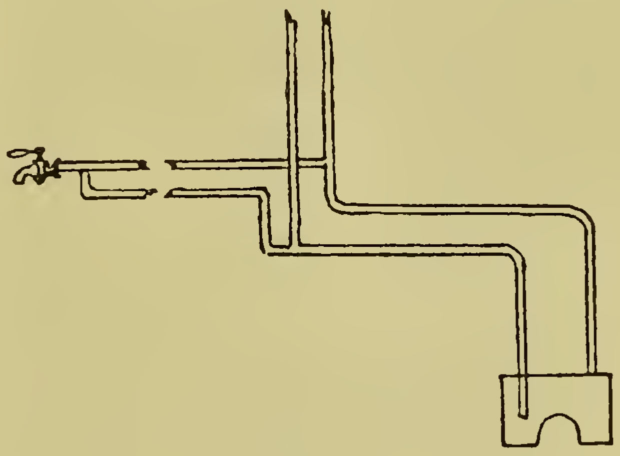

Fig. 297.

floor higher or lower, or being taken into the tank near the top. A bath service rarely needs to be returned, as some cold water is nearly always wanted at a bath, and it is immaterial which tap it proceeds from.

The main return pipe is brought from the lowest point in the tank, either from the bottom, or from the side near the bottom, and from thence to between half and three-fourths the way down the boiler, either through the top or side. It may be mentioned here that it is best to connect these pipes into the top surface of the boiler, as bends and elbows, objectionable at any time, are particularly objectionable close to the boiler if hard water is used. Deposit always seems to collect within them more readily than in straight pipes. It is usual for the return pipe to follow the flow down, and an endeavour is generally made to prevent this pipe rising or ascending anywhere on its way down from tank to boiler, and no pipes are connected to this except the "returns" of draw-off services.

In the illustration, Fig. 295 (p. 434, *ante*), it will be noticed that there is a pipe proceeding from the top of the tank, and carried from there to above the level of the cold water cistern; this is the expansion or steam pipe, and its use is to permit the free escape of any steam that may be formed, and also, as its name implies, to permit of the expansion of the water when heated. The difference in bulk between water at 32° (freezing) and water at 212° (boiling) is one in twenty, that is, twenty gallons of water at the former temperature would fill a twenty-one-gallon vessel when raised to boiling temperature.

This expansion pipe is usually of 1-inch or 1¼-inch tube, sometimes only ¾-inch when the apparatus is small; and its top extremity should be at least 3 or 4 feet above the cold water level. It is necessary to terminate this pipe either over the cold water cistern, or through a roof or outer wall, as water drips from it; and if the boiler overheats hot water may be ejected by the steam as it escapes. It is most usual to carry this pipe over the cold cistern, as carrying a pipe through the roof necessitates a little greater trouble and expense, but at the same time a drawback exists in terminating the pipe over the cistern, as any hot water that is thrown out falls into and tends to warm the cold water. This is exceedingly objectionable in the hot summer months, and it is at this time that it happens most frequently, the demand for hot water then being small, and the boiler having every opportunity to overdo its work. When possible it is best to carry the pipe through a wall, but see that it is not over any part of the premises where people may pass or stand under.

The lower extremity of this expansion pipe should not project through inside the tank, for the reasons explained in regard to the flow pipe in the boiler ; this is very commonly overlooked, as, unless a flange is ordered to be put on the tank, it is difficult to avoid it. The trouble that may arise, however, is not nearly so great as in the other case, for in a general way very little steam finds its way to the top of the house, it being condensed as it passes up the flow pipe. If the boiler heats well, or is a little too powerful for the apparatus, some annoyance must be experienced, and care should be taken to avoid dipping this pipe inside the tank whenever it can be avoided.

We have now to speak of the pipe or service which brings the cold water to the tank as fast as any of the hot is withdrawn.

The "cold supply," as this pipe is called, is brought from any low point in the cold water cistern, and from there it is carried to and into the hot water apparatus. There are many different opinions as to where this service should be connected, some recommending that it be taken into the return pipe near the tank, others that it be taken into various places in the tank, and advocates can be met with for taking this pipe down to the boiler. What has to be considered wholly and solely is that the inflowing cold water must not materially affect the temperature of the hot water, *neither must it be possible to have cold water issuing from the hot taps before all the hot water is withdrawn.* It is not necessary to go into particulars just now, but it may be taken for granted that the best place to bring in the cold supply is at the bottom of the tank, as far removed from the return and flow pipes as possible. The reason for this will be clearly understood presently.

It will have been noticed in Fig. 295 (p. 434, *ante*) that the "cold supply" service pipe is carried down with a dip before entering the tank. This dip in the pipe is called the "siphon" (not by any means a correct term, as it is not called upon to answer the purpose of a true siphon, nor could it do so in this inverted form), and it answers the purpose of preventing hot water finding its way up the cold supply into the cold water cistern, which it would quickly do if the pipe was carried straight from cistern to tank. This dip or "siphon" is usually about 6 to 8 inches deep, and its purpose is fulfilled by the fact that hot water, being of less specific gravity than cold cannot descend and overcome the superior weight of the latter. It will be understood, by referring to pp. 408, 409, that when hot and cold water are set in motion by their different degrees of gravity, the hot water has no power to descend until it has lost its heat.

This pipe is usually ¾ inch or 1 inch diameter (all water pipes are measured internally), depending upon whether the apparatus is a small or a large one, and it should always be provided with a stop-cock so that, when needed, the apparatus may be emptied without drawing off all the cold water in the house, or without plugging the cold water cistern. The stop-cock should have two special features: the first being that it should have a loose key, as it should never be interfered with except by those who understand its use (this tap should also have a distinctive label, as there are often several stop-cocks in a house). Secondly, it should particularly have a "full way"—i.e. a 1-inch cock should have a 1-inch clear way through it, as an impediment of any description in the cold supply may materially interfere with the full flow of water from any and every part of the apparatus. It will be seen clearly that it is useless having a 1-inch service pipe if the stop-tap has only a ¾-inch way through it.

It used to be the regular thing to fit up a small supply cistern, with a ball valve, at the side of the tank; but few could ever explain why it was used, and as in the majority of instances it was not only useless, but an actual drawback in impeding the free inflow of cold water, it soon fell into disuse, and cannot often be met with now. An instance where this arrangement is a desirable one is when the cold cistern is situated at the top of the house (as usual), and hot water is only required on the ground floor. In this case, to save carrying the expansion pipe to the top of the building, a supply cistern may be fitted, as Fig. 298.

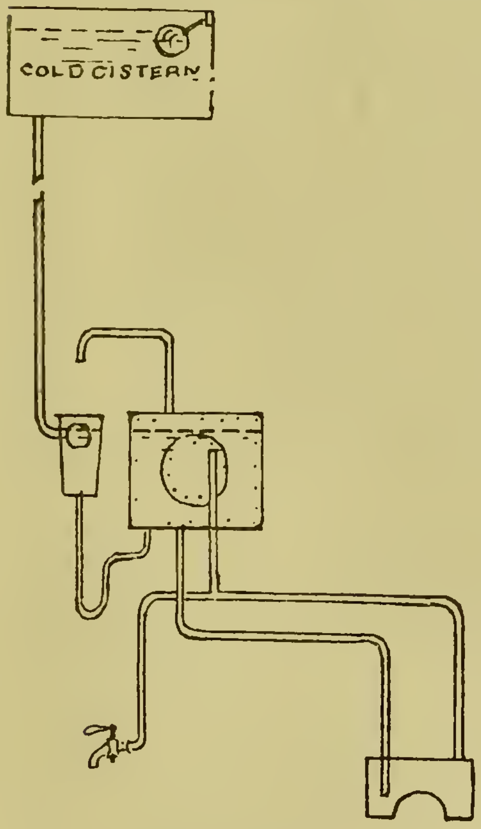

Fig. 298.

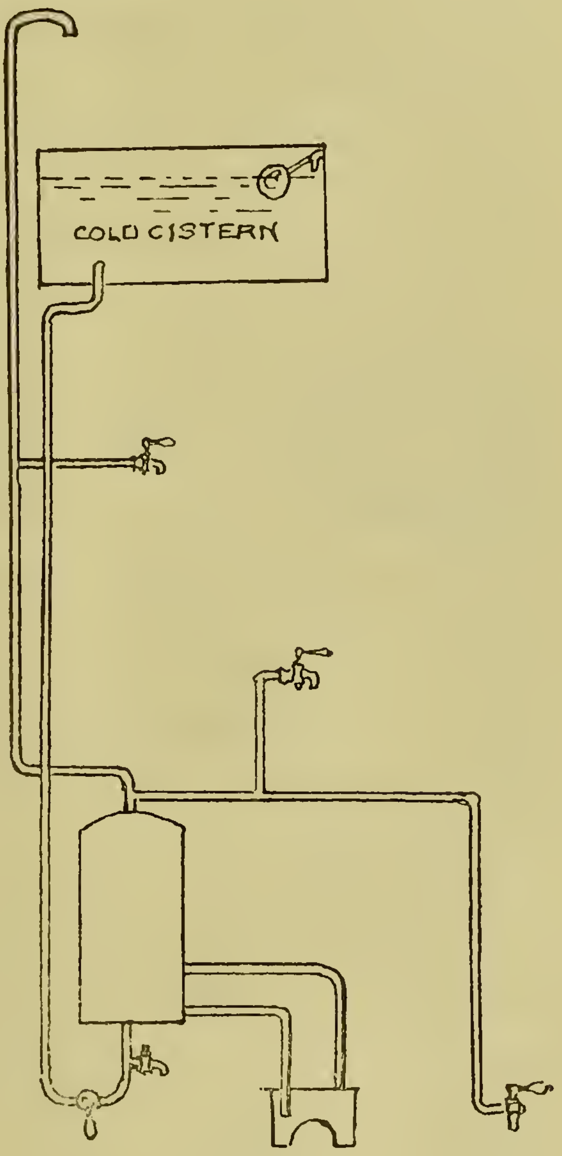

Fig. 299.

THE CYLINDER SYSTEM.

This more modern apparatus is supposed to be of American origin, and the chief feature in it, as can be judged by its name, is the cylinder which acts as the hot water reservoir, and it is necessary to explain, first, why a cylindrical reservoir is used with this system, instead of the more familiar rectangular tank.

This apparatus, which is illustrated at Fig. 299, has the hot water reservoir in quite a different position to that in the tank system, and the prevailing idea to be followed, and which is one of the chief advantages gained in erecting this apparatus, is to have the reservoir as little above the level of the boiler as possible. All the draw-off services are taken from above the reservoir, which is exactly contrary to the plan adopted in the last system explained.

The reason that a cylinder is used in place of a tank is simply that the former is capable of bearing a much higher pressure of water than the latter. A cylinder has quite commonly to withstand an internal strain of 25 lbs. to the square inch, which a tank would be totally unsuited to bear. The strongest of these latter, made of, say $\frac{3}{16}$-inch plate, are not guaranteed by the makers to withstand such a pressure as this; but a cylinder of $\frac{1}{8}$-inch plate is always supposed to be tested to 25 lbs. before it leaves the manufacturer's works, and a tank or cylinder can always be worked up to the maker's tested pressures.

Tanks are and can be used in place of cylinders sometimes when the pressure is light, but unless it is very light indeed some trouble is nearly sure to ensue, especially if the tank does not come from a good maker. In making tanks it is supposed and intended that they shall not be fixed more than a very few feet below the cold water level under any circumstances. Of course, what leads people to use tanks if they have a reasonable excuse for so doing is the desire to economise, as they cost so much less than cylinders. For instance, one of our best maker's lists prices a 40-gallon tank, $\frac{1}{8}$-inch plate quality, at 2*l.* 11*s.*, whereas a 40-gallon cylinder, $\frac{1}{8}$-inch plate quality, is priced at 3*l.* 6*s.* The practical difference, however, is not so very great, as it must be borne in mind that there is a very considerabe variation in the pressures they will bear. It is fairer to compare them in this respect when the difference assumes quite another aspect; for instance, a 40-gallon tank tested to 10 lbs. per square inch ($\frac{3}{16}$-inch plate) is priced 4*l.* 1*s.*, and a 40-gallon cylinder, tested to 15 lbs. (14 gauge), is 2*l.* 14*s.* only.

To locate the position of the cylinder first, it is most usual to put this in one of the recesses that are nearly always to be found on either side of the kitchen chimney breast. If it is impossible to place it here, it can be fixed up in another room, but it must be noted that the proper place for it is as close to the boiler as it can be got, in as warm a position as possible, and the bottom of the cylinder to be between, say 12 inches and 30 inches above the top of the boiler.

Between the boiler and the cylinder is carried a flow and return service, as illustrated, and on precisely the same principle explained in the tank system, although much shorter; but it should be explained here that cylinders are never sent out with manlids at the side unless expressly ordered. They often have removable tops, as shown in Fig. 300; but without a side manlid it is very awkward to reach the pipe connections inside at the bottom, if it is desired to do so. Most makers will put a side manlid to the medium and better quality cylinders at same charge (in which case the top is a fixture). This is much the more convenient arrangement, but it is necessary to specify it when ordering. It is also most necessary to have flanges put on in the required positions, as illustrated, as it makes a poor job connecting the pipes without them. There is no extra charge for these, and there should be one for each flow and return pipe, one centrally on top, for the expansion (or rising main, as it is more often called in this system), and one centrally in the bottom for cold supply.

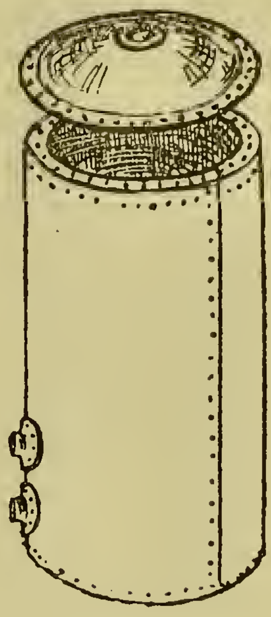
Fig. 300.

From the extreme top of the cylinder is carried a service pipe known either as the expansion pipe, or "rising main." This is taken by the most convenient way to about 3 or 4 feet above the level of the cold water cistern at the top of the house, and its upper extremity is terminated in any of the ways explained with the expansion pipe of the tank system. This pipe should be fitted and run in the same manner as a flow pipe—that is, it should only be carried in horizontal or ascending directions (the former to be avoided if possible), and it is from this pipe that all draw-off services are taken, as illustrated in Fig. 299, p. 443, *ante.* When this pipe is of considerable length, or carried in a horizontal direction to any great extent, it is found desirable, and oftentimes absolutely necessary, to return it so that the water it contains may circulate and not become cold. This is a very simple matter indeed, as it is merely to connect a service-pipe at any convenient point, usually close to the highest draw-off service, and carry it down and connect it into the cylinder—in fact, make a secondary flow and return from the cylinder, fitted in general respects like the primary flow and return from a boiler. One particular advantage of this secondary return is that it need not come back alongside the rising main; it may be brought back by any other desirable route, which is a great convenience when the hot water taps are wanted scattered about in different parts of the house. There is no objection whatever to connecting draw-off services from this return pipe, as in Fig. 301.

There is much difference of opinion as to where the lower end of this return pipe should terminate. Every imaginable place is suggested, and it would be almost difficult to find two average fitters agreeing exactly on this point. In the last illustration it will be noticed that the termination is made about a fourth of the way down the cylinder, and although this is a position that only a minority of fitters adopt, yet a very short explanation will show that it is the only correct one to obtain the best or even ordinarily good results.

In the first place, we have to aim at being able to withdraw every drop of hot water from the apparatus before having any cold water come from the taps. In seeking to attain this we have always to bear in mind that when a tap is opened the water instantly rushes from all directions towards the tap in question (the arrows on the last illustration indicate the direction the water takes when a tap is opened, not the direction in which the water circulates when the taps are closed), therefore it will be plainly seen that as the hottest water may be reliably looked for at the top of the cylinder, it would be bad policy to connect this secondary return any lower down than shown. It is especially bad to connect it into the bottom of the cylinder where the cold water enters, as is most usually done. There would be no objection to connecting it even higher than illustrated, as every particle of hot water rises to the top of the cylinder before it leaves the apparatus; it will also be seen that to connect this pipe into the primary return is bad.

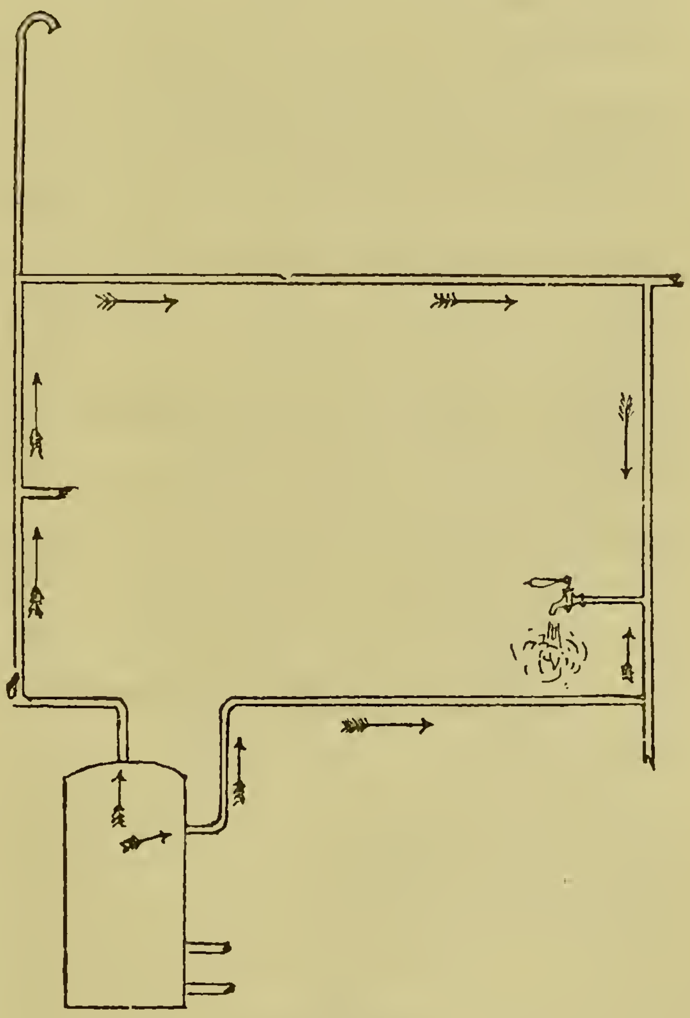

Fig. 301.

If it is not required to connect any draw-off services from the secondary return, this pipe may be reduced in size.

The cold supply service is brought down from the cold water cistern to the cylinder, where it is usually connected in at the bottom, as illustrated. Some people, however, connect it into the primary return, and some consider that the boiler itself is the best place to bring the cold supply into. In general good results the bottom of the cylinder is the most satisfactory; but in another chapter will be shown a method of reducing the length of this cold water pipe in some instances.

The necessary dip, and stop-cock, have to be put in this cold service the same as explained with the tank system.

There is a rather important feature that should always appear in this system, but which somehow is very commonly overlooked, even by those who profess this work; it is a means of emptying the cylinder when the boiler has to be opened for cleaning or any other purpose. It is not by any means an uncommon thing for a workman to find when he attempts to open and clean out a boiler, that there is no provision for emptying the apparatus, except by the draw-off services which are all taken from the rising main above the cylinder. He therefore has but two resources—one to leave the boiler unopened and uncleaned, the other to take the manlid off the boiler and let the contents of the cylinder flow into the kitchen. Sometimes the cylinder can have its top removed, and the contents siphoned out with a piece of tube into receptacles, but the removal of the top is a troublesome task usually.

The proper thing is to have a short draw-off service fitted below the cylinder, either from the cylinder itself or from the primary return; or from the lowest point in the cold supply service. The tap of this emptying service must have a loose key, which should be kept with the key of the cold supply stop-cock, so that neither of these taps may be used, except by a competent person, as already explained.

The cylinder system has several advantages that the tank system does not possess, but the chief of these is the immunity that it ensures from any danger arising from shortness of water. It will be gathered from the description given that it is most necessary that all ordinary draw-off services be connected to the rising main (above the cylinder), making it impossible for the contents of the cylinder to be drawn off except by the special emptying service. Therefore should the general supply of water run short, the fire can still be used in the ordinary way, even for a day or two—that is, until the whole of the water in the cylinder is disposed of by evaporation.

This advantage alone is sufficient to recommend the system, especially in country residences, where the supply of water is wholly dependent upon an odd man's attention to a pump, and it is almost wonderful that accidents are so rare under these circumstances.*

One point requiring every consideration in hot water supply is the pressure exerted by water, either in pipes, or the vessels which are used as reservoirs. The pressure of water in pipes is generally calculated by the power it exerts in a pipe having an internal area of 1 square inch (this would be about a 1¼-inch round pipe). A pipe of this size, 2 ft. 4 in. long, placed vertically and filled with water, would be found to weigh 1 lb. more than when empty—that is, it contains 1 lb. of water. In other words, a column of water, 2 ft. 4 in. high and 1-inch square, weighs 16 oz. It is usual to define the pressure of water as so many pounds to the square inch. The word "pressure" might very well be replaced by the word "weight" in some instances, as it is necessary to understand that the strain exerted only varies as the quantity of water varies, and variable pressures cannot be had from a given quantity of water, as can be had with steam or gas, water being practically incompressible.

Water in horizontal pipes exerts no appreciable strain, so that in calculating what pressure has to be withstood, it is only necessary to measure the distance the pipe extends vertically. If the cold water cistern is situated 35 feet above the cylinder, then this latter should be of sufficient strength to withstand a pressure of 15 lbs. on every square inch of its internal surface.

When a pressure of water is exerted from a pipe into a close vessel, that pressure is transmitted to and felt equally in all parts of the vessel in question—top, bottom and sides, without diminution. In other words, if the supply pipe descends vertically 35 feet, the water within it will exert a pressure of 15 lbs. to the square inch, and this pressure will be felt on every square inch of the cylinder internally. This makes it easily understood why these reservoirs need be so well and strongly made, the strain which some of them have to bear being very great.

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* Modifications and improvements of the cylinder system are given on pp. 481 to 490.

The following, taken from the list of a London maker, will show the great difference that exists between tanks and cylinders in resisting pressure, and it will be readily seen why a tank is not suited for the cylinder system of apparatus :—

Riveted and galvanised iron rectangular close tanks, for hot water.

Thickness of plate	$\frac{3}{16}$ in.	$\frac{1}{8}$ in.	14 g.	16 g.
Tested to, per square inch	10 lbs.	5 lbs.	3 lbs.	1 lb.

Riveted and galvanised iron cylindrical tanks, for hot water.

Thickness of plate	$\frac{3}{16}$ in.	$\frac{1}{8}$ in.	14 g.
Tested to, per square inch ..	40 lbs.	25 lbs.	15 lbs.

In regard to the pressure of water from pipes into closed vessels, it should be remembered that the same strain is exerted upon the internal surface of the cylinder or tank with whatever sized supply pipe may be used, whether it be $\frac{1}{2}$-inch or 1$\frac{1}{2}$-inch or larger. This result may be stated as follows. If the water within a pipe having an internal area of one square inch exerts a pressure of 1 lb. for every 2 ft. 4 in. of its vertical height on every square inch within the cylinder, a pipe having an internal area of half this size will only exert half the pressure, i.e. half a lb., or a pipe having an internal area of two square inches will cause a pressure of 2 lbs. But with the $\frac{1}{2}$-inch pipe the pressure of half a lb. will be felt on every half square inch in the cylinder, and with the 2-inch pipe the 2 lbs. will be exerted on every two square inches, so that the total result is precisely the same.

In purchasing tanks or cylinders it is very desirable to get them from makers who have a repute for good quality work. No doubt there are small firms who supply excellent goods, but to purchase tanks or cylinders at a low price will almost certainly prove to be false economy, and nothing is more annoying than to find, when charging a new apparatus to test it, that the tank or cylinder leaks at the joints or rivet holes. It is also unadvisable to use these reservoirs of too light a quality, i.e. those tested to a less pressure than they will have to bear. This is very often done with impunity, as of course, the makers' tested pressure does not indicate the bursting point, and where the pressure is only a pound or two over the makers' test figures no harm will ensue. But it is far better to have the reservoir a trifle too strong, as we have not only to think what it has to withstand now, but also that it will be expected to do the same work in some years to come, when it is beginning to suffer from wear and tear.

If a square tank is of large size, or unusual shape, it should have "stays" (rods extending from side to side) within it, as immediately pressure is exerted the sides are pushed out, and it has a tendency to become as round in shape as it can get.

The following are sizes of tanks and cylinders customarily chosen as being suited for ordinary domestic purposes where no special requirements exist. With the smallest form of apparatus having two taps (scullery and bath), 20 gallons; this size, however, will be found insufficient if the demand is more than moderate, by reason of a large family occupying the house, and 25 to 30 gallons would be found more suitable. Regard must be had to the capabilities of the range-boiler; there are exceedingly few 3-foot ranges that have boilers capable of working satisfactorily with a larger reservoir than 20 gallons.

In a little larger house, say nine or ten roomed, 35 to 40 gallons will be found a convenient size, the kitchen range being 4 feet (or 3 ft. 6 in. with a fair-sized fire and boiler). In larger property the size must be judged according to the number forming the household, and even the number is no sure index, as baths are indulged in much more by some people than others. The style of living regulates the quantity of hot water required in the scullery, and it is the bath and scullery taps that make the greatest inroad upon the store of hot water. Sixty gallons is a full size for a residence of some pretensions; it is unusual to exceed this size in private residences, except in mansions of the largest class, and with a large staff of servants (in which case an independent boiler would probably be required). Too large a reservoir is very objectionable, as it renders the work of the boiler almost futile; it is not so much a great store of water that is required as a moderate amount that can be renewed quickly.

PIPES, TAPS AND OTHER FITTINGS AND APPLIANCES.

The kinds of pipe commonly used in this work are wrought-iron steam-tube, galvanised ditto, wrought-iron gas-tube, and lead pipe. There are other kinds used in soft water districts such as copper tube, tin-lined, enamelled and glass-lined iron pipes.

The tube which has preference in the south of England, and which can safely be recommended before any other, is that first mentioned on the above list. This pipe is in general appearance much like gas-tubing, except that its substance is much greater, and in quality of metal it excels the latter. It can always be distinguished by its being coloured a dull red (except when it is galvanised), whereas gas-tube is always a natural black. Every one having a reputation to uphold uses the steam-tube; and, although a great deal of gas-pipe is to be found, it will generally be discovered in speculative work of a poor class. The difference in cost between steam and gas tube is about 30 per cent.

There is very little galvanised tube used or needed in hard water districts, as the only object of the galvanising process is to render the tube fairly rust-proof, and so prevent discoloration of the water and weakening of the pipe itself by oxidation. The lime which, as already explained, is the cause of the hardness of water, is one of the best of rust-preventives, and it fulfils its usefulness in this direction by coating the internal surface of the pipe with a thin film of carbonate in a very few days, and the rust difficulty is then quite obviated. In soft water districts, however, some non-rusting tube has of necessity to be used, as water without lime in it always seems to act so vigorously in rusting iron, and the plain steam-tube in these districts causes a good deal of trouble by its being eaten away rapidly and discolouring the water to a considerable extent. Galvanised tube, if well galvanised, overcomes the difficulty to some extent, but care has to be used in fitting it up; it will not do to forge this pipe in any way (that is, heat it for bending or setting purposes), as the galvanised surface will be injured and rusting ensue; and wherever a pipe is cut and screwed, also, the interior of the socket-joints are all places where rusting cannot be helped.

Pipes are sold which are galvanised on the outer surface only, but it is almost unnecessary to point out that this must be avoided, as no benefit is obtained by the extra outlay. Caution is also necessary to see that when galvanised steam-tube is ordered, the steam quality and strength is obtained, as this material is not kept in stock by every one, but galvanised gas-tube is.

When galvanised tube has of necessity to be used, it is, of course, somewhat necessary to have the boiler galvanised also (or of copper), as the rusting takes place in these almost as badly as in the pipes; but both galvanised pipes and boilers should only be used when circumstances make it requisite, as the acid bath and subsequent galvanising process are considered to be rather detrimental to the iron.

Lead pipes, and copper boilers and reservoirs, are most commonly used in the North of England, particularly in the Manchester and Liverpool districts, where the soft water requires every consideration. Lead pipes certainly do not rust, but there are other disadvantages connected with this material. For instance, it has been forcibly brought to people's attention that soft water has as vigorous an action on lead (the lead of commerce) as it has upon iron, and the lead which is separated or taken into solution by the water has brought about many serious epidemics of lead poisoning, or plumbism, in various districts. This has led to the introduction of tin-lined lead pipe, that is, lead pipe having its interior surface of metallic tin, which is not acted upon by soft water in the way described. Tin-lined iron pipe has also been introduced, and is having a deal of favour.

Lead pipe has another drawback in its softness. This permits of its being easily stretched, or bulged, and weakened by every strain that it is subjected to; on this account it is almost impossible to use the sudden shutting plug-cocks with lead piping, as the jar or concussion that is occasioned every time a tap is shut soon does serious injury, weakening the pipe and necessitating repairs. This is most noticeable with the taps at the bottom of the house, where a considerable pressure of water may exist, and in these situations the slow-closing screw-down taps should always be used with lead pipes.

It must have been noticed by nearly every one that when a plug-cock is closed at all sharply, where a tolerable pressure of water exists, the noise of a somewhat violent shock is heard in the pipe, and the pipe may be shaken. It is when this noise is heard that the strain is exerted which injures soft metal pipes.

It has to be remembered that water is practically an incompressible substance, and in this respect resembles a solid body, so that when we suddenly stop a stream of water flowing under a high pressure within a confined area a considerable resistance must be expected. This exerts itself chiefly in the vicinity of the tap where the greatest pressure is felt. Shutting a tap 50 feet below the cold-water cistern causes a pressure of about 21 lbs. to be brought to bear on every square inch of pipe surface near the tap in question. If the tap is closed slowly the strain is reduced to a minimum, but if closed sharply the strain assumes the character of a blow. The tin-lined lead pipe referred to overcomes this trouble to some extent, as tin is harder and of a more rigid nature than lead, but, of course, not so much so as iron.

The different strains brought to bear in this work have not only the effect of bulging and weakening lead pipe, but also an even worse effect in causing the pipe to be stretched lengthwise, which ill effect is of greater frequency than the bulging. An instance of this recently came under notice (in London) in which lead pipe of a very fair weight had been used, but which proved to be a very marked failure. This was partly due to insufficient hooking up and partly to a considerable length being carried up a high, straight casing in which it was difficult to give it good support. The result was that the horizontal pipe sagged down between the hooks, and the vertical pipe became lengthened several inches by its own weight and the pressure of water within it, so that in a few months it was exactly as Fig. 302. In this instance the contractors were compelled to renew the whole apparatus in iron at their own expense.

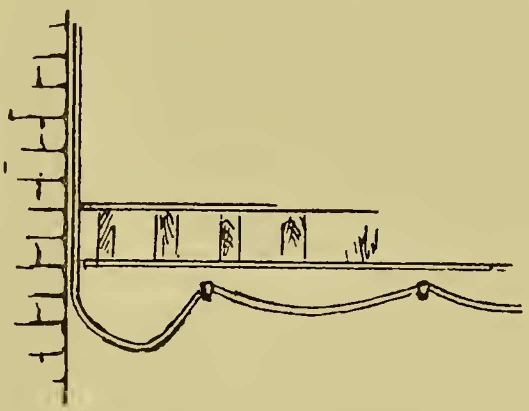

Fig. 302.

When the flow and return services are lead pipe it is generally necessary to have the ends nearest the boiler of iron, the former material being fusible at a moderately high temperature, and fusing is likely to occur if the pipes are furred or if the boiler is emptied (by a workman) immediately after the fire is extinguished and before the surrounding metal and brickwork have lost any of their heat.

An important point which, up to the present, has only been just touched upon, is the size of pipes most suitable for different services and purposes. This, like many other matters connected with hot water supply, is greatly regulated by the fur difficulty, which makes it necessary to use much larger pipes than are needed in soft water districts. There is a definite limit as to the size of pipes; and although comparatively large pipes are always recommended for the two reasons about to be explained, yet to increase the pipes beyond a certain point is not advantageous.

A large pipe is considered to be conducive to a freer circulation—that is, the water can travel from boiler to tank at a greater speed on account of the lessened friction, and it is certainly beneficial for the water to leave the boiler as fast as possible when it has absorbed heat; but this advantage alone would not be generally considered of sufficient importance to warrant the great cost of larger pipes and the increased labour in fixing them. The reason which sanctions the greater outlay will be found, in nearly every case, to be the wish to lengthen the time in which pipes become furred up and require renewal.

One-inch pipe is very largely used for the main flow and return services, and it is a size that will give fairly good results so long as the passage within it remains an inch; and even when the incrusted deposit has reduced the bore to ¾ inch there is seldom cause for complaint (unless the apparatus is on a rather large scale). 1-inch may, therefore, be considered a suitable size in soft water districts for moderate sized domestic work; but if the apparatus is of a large size 1¼-inch is better. In an hotel or institution 1½-inch is more often requisite.

In hard-water districts, 1¼-inch is best for ordinary residence work, but if, in a tank system, the flow and return pipes are of considerable length, an economy may be permitted by reducing the size to 1-inch, say 20 feet from the boiler, as the incrustation will be found in almost every instance to be much less at the tank end of a long pipe than near the boiler. In a cylinder apparatus, unless very small, the short flow and return from cylinder to boiler should always be 1¼-inch or 1½-inch; all other pipes in this system may be smaller.

In the tank system the expansion pipe and cold supply for moderate sized work may both be ¾-inch, but for a good sized residence, where a fair demand for hot water exists, the supply pipe should be 1-inch, and the expansion should be increased to 1-inch or 1¼-inch. The sizes of the draw-off services should be, 1-inch pipe for baths, ¾-inch for scullery, pantry, housemaids' sinks and general purposes, ½-inch for lavatory basins and any small purpose; these sizes, for draw-off services, are usually adopted in both small and large works on any system.

In the cylinder apparatus the primary flow and return should be 1¼-inch or 1½-inch as mentioned; the rising main or secondary flow may be ¾-inch in small property, but never less than 1-inch in work of a fair size. If this pipe is returned (forming a secondary return) this may be ½-inch or ¾-inch, according to the magnitude of the installation, and the cold supply should be either ¾-inch or 1-inch (with a full way stop-cock), also according to the importance of the work in hand. The great objection to a small cold supply service to the cylinder system is that it reduces, i.e. checks the flow of water from the taps of the apparatus.

When a pipe becomes furred, the bore becomes reduced in size, and would, if permitted, eventually become quite stopped, perhaps ending in an explosion at the boiler. An explosion from this cause, however, has most probably never occurred, for, before any real danger exists, such violent noises and vibrations are noticed, that an experienced man is called in, owing to the apprehension of danger that arises. It is generally when the bore has been reduced to about ⅜ inch (depending, however, upon the power of the boiler) that the noises are first heard, and which are caused wholly by the steam being unable to escape freely. Usually the flow pipe gets the greatest share of the fur, in which case the violence arises by some proportion of the steam forcing itself into the return pipe.

A 1¼-inch pipe will last nearly double the time a 1-inch pipe will before giving trouble, as, in the first place, a ¼-inch deposit is longer in accumulating on a 1¼-inch than on a 1-inch surface. When the former has a ¼-inch deposit it is still fit for a great deal of service ; whereas the latter is upon the point of giving trouble. It should be mentioned that it is commonly the case for the supply of hot water to become lessened and somewhat uncertain when pipes are badly furred, commencing before the noises are heard.

It is quite possible to have the pipes cleaned of fur when the occasion arises, but this necessitates their removal, and a somewhat lengthy job afterwards in heating and hammering them, and it will be found as cheap and decidedly better to replace them with new.

TAPS.

There is, as every one knows, a great variety of these to be had, but notwithstanding the many improvements and advanced ideas in this direction, a perfect tap, or a nearly perfect one, is by no means common. There are numbers of these articles to be met with, that display excellence of quality and careful workmanship and finish, yet few makers are prepared to supply a $\frac{3}{4}$-inch bib-tap for hot water, guaranteed to last more than twelve months without leaking, in a large residence using hard water, and where the tap is in fairly constant use—at the scullery sink, for instance.

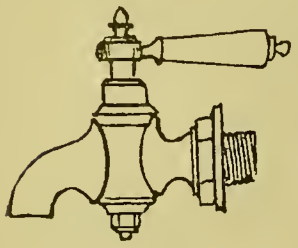
Fig. 303.

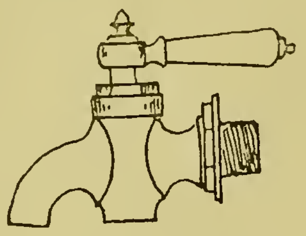
Fig. 304.

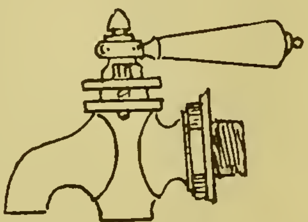
Fig. 305.

The most usual form of tap to be met with, and one which is found to give fairly good results, is that having a plug through its centre and known as a plug-cock (Fig. 303). These are made either with a nut bottom (a nut being screwed on to the plug at its lower end), as illustrated, or with a solid bottom, the plug being secured with a cap screwed on at the top, as Fig. 304, this cap forming a stuffing-box. There is another with a solid bottom, the plug being secured by a plate at the top (Fig. 305), this being called a "gland" cock. Either of the two latter are preferable to the former, as those secured by a nut at the bottom sometimes leak at that point, which is impossible with the others. These three are the forms of tap alluded to on a former page as "quick-shutting" (in contradistinction to the slow-shutting screw-down taps), and which cause the concussive noise in the pipe when shut off suddenly where a good pressure of water exists. There is a very simple remedy for this, which will at the same time check the violent outrush of water experienced when a great pressure exists. This is effected by reducing the bore of the tap at what is called the "tail," the screwed portion that enters the pipe, as in Fig. 306. This is quite understood by the makers, many of whom keep these "checked" taps in stock. Workmen sometimes do this themselves by cutting a circular piece of sheet brass or zinc, and, after making a suitable hole in it, solder it on to the end of the tail.

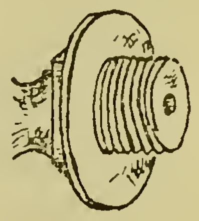

Fig. 306.

Where there is a pressure of 15 lbs. to 20 lbs. (cold water cistern situated 35 feet to 46 feet above the tap), the hole in the tail of the tap may be reduced to $\frac{3}{16}$-inch ; with a 10-lb. pressure a $\frac{1}{4}$-inch hole is ample.

Screw-down taps overcome the concussion difficulty, by its being impossible to close them suddenly ; but these taps, however well made, require "re-seating" periodically, that is, the seating or diaphragm, whether rubber, leather, or composition, requires renewing periodically. If the tap is not of good quality the thread of the screw-down arrangement wears or strips off quickly. This style of tap is now largely used, but it has an opponent in every servant that has to use it, as it cannot be opened or closed quickly. In many busy houses a tap is oftentimes applied to a dozen or more times per hour, in which case the unscrewing and screwing usually leads to a loss of temper.

There is a modified form of the screw-down tap now being made which can be opened or closed in one turn, or they can be had to open or close with a half turn, which is as quick as a plug-cock ; this overcomes the difficulty just referred to, but a new disadvantage is introduced with them. When the abrupt thread of the screw-down arrangement wears loose, a fair pressure of water will lift the seating slightly, and permit of leakage, and the thread of a screw-down tap is a troublesome part to repair.

It is now considered best, when purchasing baths or lavatory basins, to choose those that have the hot and cold taps fitted and attached to them, so that the connection of the pipes to the unions provided is all that is needed to complete them. This is a much better and neater arrangement than having the taps projecting from the wall over the basin or bath, and it not infrequently happens, when this is done, that the hot and cold taps will be found of different patterns, as the hot and cold draw-off services are so commonly fitted up by different tradesmen (hot water fitter and plumber). When the taps are fitted to the bath or basin by the maker they are sometimes placed out of sight, only the handles being visible, these having porcelain discs upon them marked either "HOT" or "COLD," and altogether a very superior result is effected with very little extra cost.

It has been the usual practice with makers, when supplying baths fitted with taps, to place the taps in question on, or nearly on, the rim of the bath, so that the water issuing has to fall about 18 inches ; this is no great objection with the cold water tap, but with the hot tap it is an annoyance, as the falling hot water throws clouds of steam into the room, making it very unpleasant, particularly if the room be small. This objection is overcome by having the hot water inlet situated near the bottom of the bath (not in the bottom itself), so that it is quickly covered with water, which prevents the steam arising ; it is as well to have both hot and cold inlets thus situated, as the bath will then fill noiselessly. Baths so fitted are generally described as having steamless and noiseless fittings.

This arrangement must not on any account be confounded with the method adopted in the old pattern zinc and copper baths to be met with, wherein the hot and cold water enters through the waste grating in the bottom of the bath. The particular objection to this is, that when the bath is emptied after bathing, a certain amount of soapy, objectionable sediment is always left just in the waste outlet beneath the grating, and this substance is washed back into the bath by the inflowing water when the next person makes ready to bathe.

It is very desirable to have fair sized service pipes carried and connected to a bath, and the taps should be as large as possible, say 1 inch, as a slow-filling bath is as much a source of annoyance as one that empties slowly.

The majority of best quality and even many cheap-made baths are now fitted with the taps and with soap and sponge trays, all *within* the bath ; this is an excellent feature, preventing drip water and soapy matter finding its way to the floor, or if the bath is encased it prevents the woodwork being injured from the same cause. When the bath taps are placed on the wood bath rim there is invariably a collection of dirt there, unless they are very carefully cleaned, and in this latter case the cleaning leads to the polish being rubbed off the woodwork and creating an unsightly appearance around the taps.

A very useful and not expensive adjunct to a bath is a shower apparatus ; the old form of this appliance was a most inconvenient and troublesome thing, as it consisted of a suspended vessel or reservoir which had first to be filled before allowing its contents to be showered down. This, although cumbersome and unsightly, answered very well with cold water, but if a warm or tepid shower was required there was no way of testing the temperature except by climbing up and testing it with the hand ; otherwise the result would be most uncertain, if not risky.

The more modern form of shower attachment is as Fig. 307, consisting of a board of polished wood (to match the bath casing) on which is fixed the hot and cold taps and the shower rose. The method of connecting the pipes is shown at Fig. 308, which illustrates the back of the board. It will be seen how simply the temperature can be regulated, so that, if desired, the water can be gradually made to vary from warm to cold, and the shower can be continued any length of time. A further useful adjunct which can be attached to the shower board inexpensively is a small tap with a nozzle, to which can be secured a piece of india-rubber tube. This, if fitted with a rose, can be used either for shampooing purposes or for rinsing out the bath after use.

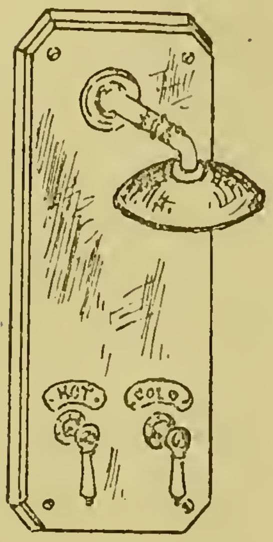

Fig. 307.

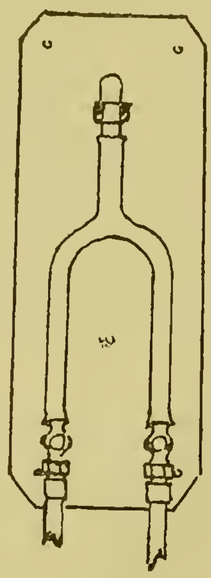

Fig. 308.

COVERING PIPES AND RESERVOIRS FOR THE CONSERVATION OF HEAT.

There is no branch subject in connection with hot water work deserving so much attention as this. It is no exaggeration to say that very shortly an apparatus for hot water supply will not be considered complete or finished if the whole system is not insulated, so to speak, so that almost every particle of heat absorbed by the water in the boiler will be obtainable from the taps. Instead of this nearly 50 per cent. of the heat is radiated from exposed surfaces in many cases, and worse than wasted.

There are at this moment hundreds, if nor thousands, of hot water systems that, by being carefully covered, would be converted from miserably inefficient to highly satisfactory appliances — this in particular with the tank system, the tank being so commonly fixed in a cold, draughty roof.

An interesting instance of the success attending the covering of pipes occurred quite recently, in which a residence was fitted with a complete system of hot water supply pipes on a scale sufficiently large for a good boiler in a 5-foot kitchen range. Owing to a delay experienced in obtaining the range in question, another of a smaller size, 3 feet, was fitted up and connected to the chimney and circulating pipes, for temporary cooking and hot water supply. It was not supposed that this little range with its boiler would do much in the way of water heating, but to the astonishment of every one it gave a really abundant supply of very hot water in every part of the house as quickly in the morning and altogether as satisfactorily as a larger range would be expected to do.

This desirable result was wholly brought about by the pipes and cylinder being everywhere carefully covered with a sufficient thickness of felt, so that however hot the water was within the pipes, no heat could be felt outside the covering, a sure indication that no heat was being dissipated.

It really does seem opposed to all reasonable and workmanlike principles to allow such abundant opportunity for heat to be thrown away, while labour and fuel are being expended in the kitchen apparently for this object. If a fitter or maker of steam engines and appliances did not attend to this subject in a thorough and workmanlike manner he would be considered to have hardly mastered the rudiments of his business. The waste of heat is not always the only ill-result experienced, as in many instances the warmed air is very objectionable, and if a hot water pipe is carried alongside a soil-pipe it is possible for a very unpleasant feature to introduce itself. It is a very customary practice for a hot water fitter to carry his pipes up in the casing that is nearly always to be found passing from the bottom to the top of the house, this casing containing all the different pipes of the house, such as the cold service from the main, the cold service down from cistern, the W.C. cold water services, and, very commonly, the soil-pipe. There is no objection to his making use of this casing if it is large enough to hold a few more pipes, and it is often used of necessity, as to carry pipes openly through well-decorated rooms is out of the question. But to carry hot water pipes up this case without protecting them is an exceedingly bad practice, as they are not only brought into contact with very cold surfaces (they have frequently been found wired on to cold pipes, four or five pipes in a bundle), but the heat radiated causes a draught or current of air to set in, as we find in a chimney.

When a casing contains pipes that radiate heat, that casing, within a few moments after the heat is felt within it, is converted into a flue, as by applying heat to air it can be made to circulate to all intents and purposes like water. Air that is brought in contact with heated surfaces becomes heated and rarefied, and, being thus made lighter than the surrounding air, rises, and cold particles immediately flow in to take its place, they becoming heated and following the first particles, and so on. It thus resolves itself into a stream of warmed air, flowing out of the upper part of the casing, and cold air flowing in in corresponding volume below. This may be excellent in practice when hot water pipes are used for effecting ventilation, but it is fatal to hot water services which are particularly required to keep the heat within them. In many instances they are cooled at about the same speed as they would be if placed outdoors when a strong wind was blowing.

It may be argued, that if the casing is stopped off at its two extremities, the trouble will be obviated ; and so it would be if the casing was perfectly air-tight everywhere, and had no cold pipes within it. This, however, is never the case, there are always numbers of crevices and apertures which permit of a tolerably free ingress and egress of air.

The best material for covering these pipes, and also the reservoirs, is hair felt ; hair is a natural poor conductor of heat, and nothing surpasses it for this purpose, especially as it is so easy of application. This felt, which is readily obtainable in sheets, is usually cut up in strips for pipe-work ; the strips are wound upon the pipe spirally, being secured here and there with cord or wire, but where spiral winding is impossible it can be tied on in lengths, which answers equally well but has a very untidy appearance if exposed to view.

A more complete arrangement, largely practised for pipework, but which entails a little greater expense, is to have the felt wound on spirally in one direction, say from left to right, and well secured with cord ; then cover this with good canvas, also wound on, but in the opposite direction, and this secured with wire.

There have been two or three different sectional pipe coverings introduced, chiefly with the object of providing a covering easily fixed and having a good appearance. The writer has devised one of these as Fig. 309, the protecting medium coming next to the pipe being the best quality quilted hair felt. The exterior consists of pairs of stiff channel pieces, the felt being secured on the inner side as illustrated. The fixing is simply effected by thin metal bands with buckles, the bands coming 6 inches apart. The fixing is, therefore, very rapidly effected, and should occasion require, any section of covering can be removed and replaced as often as needed. The lengths are easily cut with a knife or light saw, and curved sections are made to cover bends. The felt can be had any thickness.

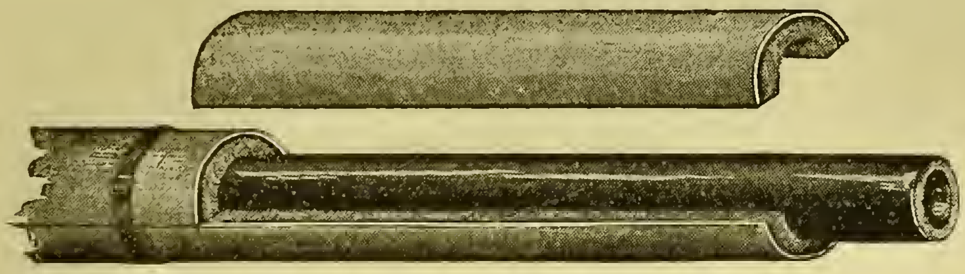

Fig. 309.

It is most necessary, to secure the best results, to have the felt thick enough ; hair felt is sold in great quantities about $\frac{3}{16}$-inch thick, but this is not thick enough for good work. If possible have it $\frac{1}{2}$ inch thick, and a marked benefit will be had by using even thicker than this.

In felting cylinders, it is the best plan to take sufficient sheets of felt, and then sew the edges together to form one sheet large enough to go all round the reservoir. This sheet can then best be secured by bands of hoop-iron, or brass, passed round at top and bottom, and around the middle; these bands being tightened up by having a bolt to draw the two ends together, as Fig. 310. After this circular pieces can be cut for top and bottom; these pieces being sewn on to the top and bottom edges of the large sheet. Tanks can be covered in exactly the same way.

Sometimes it is desired to encase the tank or cylinder with woodwork. This makes by far the neatest job, though more expensive, and it causes a little trouble should it be necessary to open the reservoir, unless provision is made for this. If it is decided to have a casing, it is very important that the space between the woodwork and the reservoir be well filled-in with some poor conductor of heat, such as cow hair (plasterers' hair), slag wool, or even dry sawdust answers very well when the casing can be filled from the top. If the casing is not "packed" with something it would be much better to be without it. Without packing it will have a current of cold air passing up through it, the same as explained with the general pipe casing just referred to.

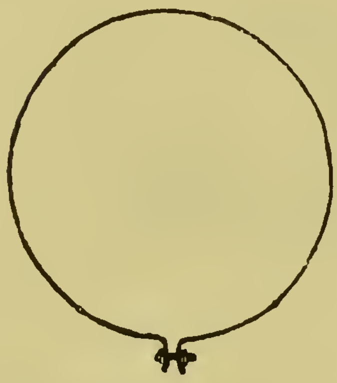
Fig. 310.

If the hot-water service-pipes are carried up through the house without entering the general pipe casing mentioned, and it is proposed to encase them for the sake of appearance, this casing must also be packed for the reasons explained. This is frequently neglected, with the worst results, the casing of pipes being frequently done for appearance sake only, the question of radiation and loss of heat not having consideration.

Occasionally it is found practically impossible to carry the pipes up inside the house, in which case it becomes necessary to take them up outside, but in this instance, casing becomes an important necessity not only to prevent the failure that must ensue by loss of heat, but also to prevent injury and danger from frozen pipes in winter. For outside work the case should be large enough to have $1\frac{1}{2}$ inch of felt between the wood and the pipes, and it should be very securely attached to the wall, for should it come away the pipes will be exposed, as they lay flat and tight against the brickwork.

A method sometimes adopted for covering outside pipes is to run them within a larger pipe, such as is used for rain water, filling in the intervening space with sand or some other material. This plan is neat and convenient in the first instance, but it is very disadvantageous should a leakage occur, when it becomes necessary to displace most of the large pipes, or to break out one of the lengths.

There are various materials in the market prepared and sold expressly for covering heated surfaces to prevent radiation and loss of heat; these generally take the form of a cement, and are largely used for coating steam-boilers and tubes in which conservation of heat is so very necessary; but these materials have not been taken to at all favourably by hot water engineers. No doubt the chief reason is that they are a little difficult of application compared with felt and some other substances, and with these latter there is less trouble occasioned should it be necessary to expose and afterwards re-cover the pipes.

As a loose material there is a substance deserving of special mention on account of its excellent qualities, and which is used alike by steam and hot water engineers. This is "silicate cotton," or "slag-wool," obtained as a waste product from blast furnaces. It is of a fine, soft, woolly nature, and an excellent poor conductor of heat. It is wholly composed of glass (silica). For packing pipe cases it excels hair, and its cost is very reasonable, being about 12*s.* per cwt.

Sand, where it can be used, is also a poor conductor of heat, being chiefly composed of silica, the same as silicate cotton; but it is not so easy of application as this latter material, which is a woolly glass. Sawdust is also used with some success, in dry places.

CONVERSION OF A TANK APPARATUS TO THE CYLINDER SYSTEM.

It very frequently happens that when any extensive repair in a house is being carried out, or from some other such cause, it is thought desirable to convert an old tank apparatus to the more modern cylinder system, and the change can usually be effected without very great expense, that is to say, at considerably less expense than erecting a new apparatus.

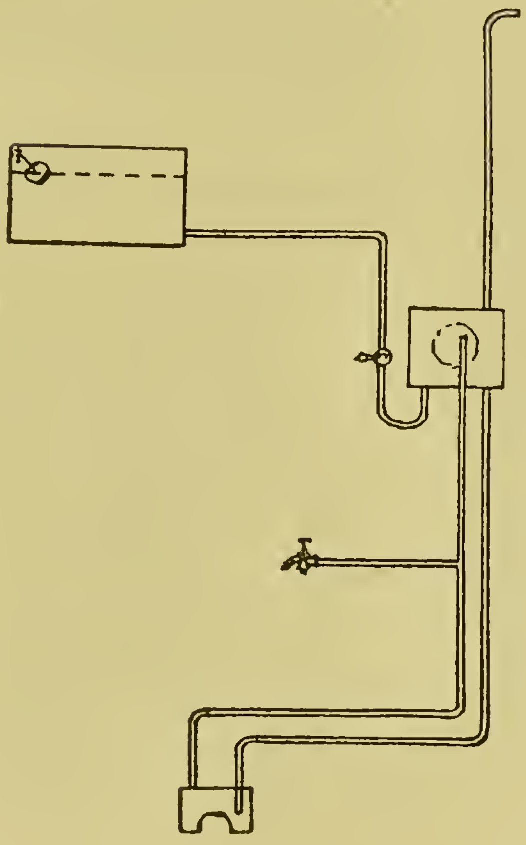

Fig. 311.

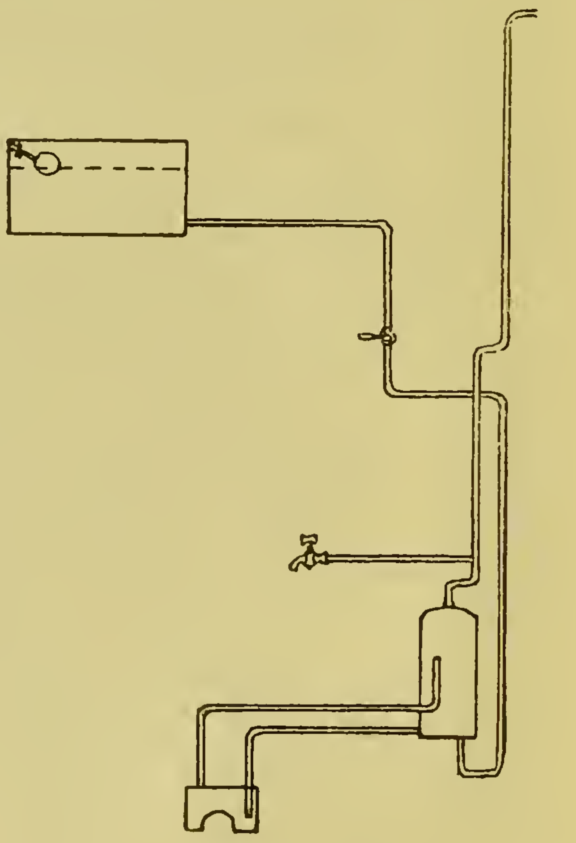

Fig. 312.

The most usual method, when circumstances will allow, is to utilise the existing flow and return pipes of the tank system for the rising main and cold supply to the cylinder, respectively. Fig. 311 shows a small, ordinary style of tank apparatus, and Fig. 312 shows the same apparatus converted.

It will be seen that the conversion requires the removal of the tank entirely by this method. The flow pipe which entered the tank has to be continued up to above the level of the cold water cistern; the cold supply service which was carried into the tank must be connected on to what was the return pipe, and this completes the alteration at the top of the house. In or near the kitchen the original flow and return services have to be cut, and the cylinder inserted as shown, the flow and return from the boiler being connected into the cylinder in the usual way. The continuation of the flow pipe has to be connected into the cylinder at the top to form the rising main service, and lastly, the lower extremity of the cut return pipe (which is now connected with the cold water cistern at the top of the house) has to be carried into the bottom of the cylinder, forming the cold supply. The stop-cock in this service, which we have left at the top of the house, can, of course, remain there, but it is much better to bring it down close to the cylinder, so that when a workman

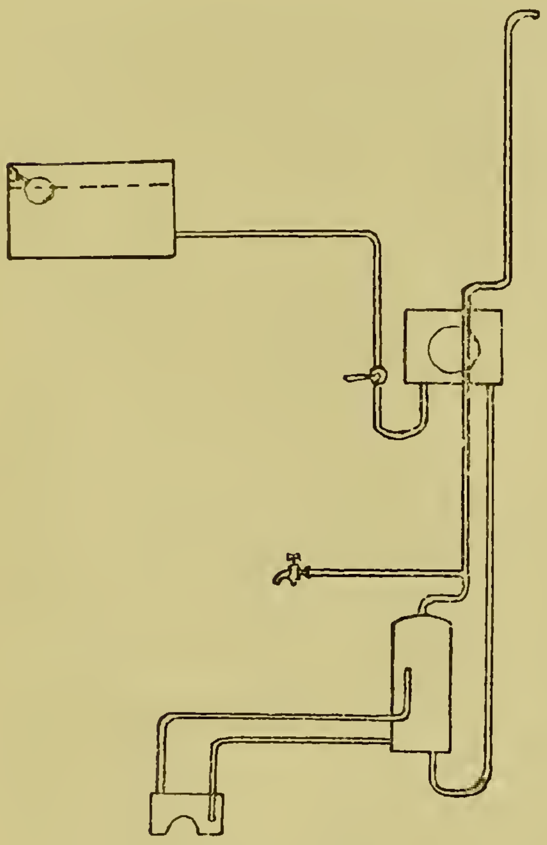

Fig. 313.

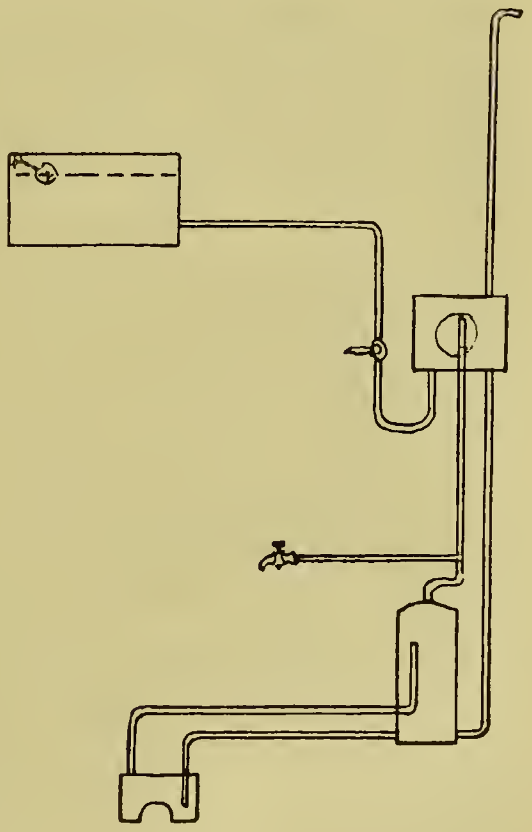

Fig. 314.

has to use it there is no occasion for him to traverse the house three or four times, certainly twice.

The alteration at the top of the house can be lessened if desired by the non-removal of the tank, this being left to increase the cold water supply. In this case the only change to be effected at the top of the house is to convert the flow pipe into a rising main carried to above the level of the cold cistern, as Fig. 313.

It will be noticed that the conversion described (Fig. 312) does not provide for the rising main being returned ; this, if it is necessary, must be a distinct and new service. It becomes a necessity should there be any draw-off services that were "returned," as otherwise there will be no service pipe to return them into. This brings to notice one disadvantage of the cylinder system, which is that a good and complete apparatus has to have three pipes down the house, whereas the tank system needs only two ; but after all, the difference is not so very great, as the pipes above the cylinder do not require to be so large as the flow and return of a tank apparatus.

Sometimes the conversion can be effected without interfering with the tank at all, but the circumstances have to be rather special. As an instance, let it be supposed that the existing tank system, which is to be converted, has a tank, say 25 or 30 gallons, which has proved to be rather insufficient for the demand. Or supposing the demand for hot water has increased and a larger kitchen range or a larger boiler is being introduced, then in either of these instances, instead of taking away the tank, it can be allowed to remain and a small-sized cylinder inserted below, as Fig. 314. It is arranged for the contents of tank and cylinder together to be, say, 50 to 60 gallons, if the range is of fair size, or according to the general requirements.

This arrangement can be but seldom resorted to, as most usually the tank will be found of ample size, and capable of fulfilling the demand, in which case to insert an additional reservoir would in all probability be more than the boiler could heat successfully; and a limited success in this work may be considered a failure.

The illustration shows exactly what is necessary in a conversion of this character. There is no alteration whatever needed in the upper part of the house, except that it must be seen that the flow pipe in the tank terminates in a high position, say, three-fourths the distance up from the bottom, and not on any account nearer the bottom than this. The insertion of the cylinder below differs a little from the arrangement last explained, as will be seen by comparing the two illustrations. The original return pipe still remains a return pipe, and instead of being connected high up into the side of the cylinder, it must be brought in at or near the bottom, as we cannot look to have much hot water in this pipe, and it must be kept away from the draw-off services accordingly.

When a conversion is effected, and it is found that a draw-off service is connected to the flow pipe below the cylinder, this service must be cut off and reconnected to the rising main above the cylinder. It will be understood that the chief advantage, the safety, of this system is effected by omitting all means of emptying the cylinder, except by the special cock with loose key that is provided for workmen's use and emergency. If, in the conversion last explained, anything would be gained by leaving the original return pipe untouched, this may be done, as no particular benefit will be effected by cutting this pipe and connecting the two ends into the cylinder; it can be left as it existed before, running from the tank to the boiler, the cylinder being inserted into the flow pipe only. This makes the cylinder to all intents and purposes like a large bulge, an enlargement, low down in the flow pipe.

This combined cylinder-tank system is often adopted by the writer when erecting new works, and no doubt it will have a deal of favour when better known. With the cylinder system, whether with single or returned rising main, there is a disadvantage sometimes experienced which never occurs with the tank apparatus, and this is the sluggish outflow of hot water from the taps on the upper floors of the house. With a tank of hot water above the taps there will be a good outflow, even if a tap is no more than six feet below the cold water cistern which feeds the apparatus ; but this is not the case with the cylinder system ; in the latter, the hot water has to ascend from below, and friction in the pipes has a more active effect. By a combination of the two systems the advantages of both can be secured, without the failings.

TWIN BOILERS AND SERVICES.

There are at this moment hundreds, if not thousands, of houses, particularly in the West-End of London, that have the old-fashioned open ranges in their kitchens, these ranges having two boilers fitted in them. These are not exactly "twin" boilers, but they will serve to illustrate their use and occasional necessity.

The object of having two boilers in these old ranges was twofold ; firstly, one boiler was considered and generally found to be incapable of providing sufficient hot water for the whole house, and it became necessary to put in two boilers with a proportionate increase in the size (width) of the fire. One boiler was used and kept distinct for kitchen supply, and the other for baths and other taps in the upper part of the house. This arrangement was so customary that makers of modern ranges are continually being asked if they are sure the one boiler in their ranges is sufficient for all purposes, and the inquirer is often incredulous if answered in the affirmative, the boiler in a modern range being only about half the size of one of the boilers in these old-fashioned ranges.

The only argument in favour of the two boilers in the range was that the demand for hot water in the servants' offices need not exhaust the bath supply, or *vice versâ*, but this argument cannot hold good with a modern range, provided it has a good boiler. The arrangement of two boilers however, became so customary that great numbers of houses will be found to have a cistern at the top of the house and another below, one being for upstairs use, and one for kitchen supply (for both hot and cold water), but this is now quite unnecessary so far as the hot water is concerned.

Sometimes, instead of two boilers a single boiler of large size was used, this boiler supplying the kitchen under low pressure. Within this boiler was fitted a coil of pipes which acted as a heating medium for a hot water circulating apparatus that was in connection with them, for bath supply, &c. This is a wretched arrangement, for, in the first place, hot water is a poor medium to heat water with, and secondly, every time a drop of hot water was drawn in the kitchen the coil was cooled to some extent by the cold water flowing into the boiler. The two boilers were better than this, but neither could possibly be recommended now.

An occasion that arises for the use of twin boilers is when the cistern at the top of the house is not large enough for all purposes, and the cistern which we must suppose exists down below has of necessity to be relied upon. It will be obvious that the two cisterns cannot anyhow be made to supply one apparatus (if any part of the apparatus extends up above the lower cistern), and it becomes necessary to have two boilers in the fire, each doing distinct work with a distinct supply This, fortunately, rarely happens, as it is an unsatisfactory arrangement, and an effort is always made to overcome the difficulty by adding to the storage capacity of the cistern at the house-top, so that it can meet all demands, and so need only one boiler. It is hardly necessary to mention that the arrangement of two boilers is much the more costly, and as it necessitates an increase in the width of the fire the consumption of fuel is greater. The range has also to be strengthened to withstand the greater wear and tear caused by the greater heat evolved, &c.

Fig. 315 illustrates a pair of boilers to go at the back of a kitchen range fire, but to get a separate flue to each it becomes necessary to have the fire of a most extravagant width, especially if both boilers are not required all day. The difficulty is, therefore, overcome to some extent by making the boilers as Fig. 316, but here a disadvantage presents itself in the fact that no means can well be devised to work one boiler independently of the other.

When a pair of boilers are really necessary, it is practically impossible to make them each of an exactly suitable size for the work each has to do. The consequence of this is that in all probability one boiler will overdo its work, and the other fail, and under any circumstances some annoyance will be felt by the boilers working unequally. A very marked instance of this is when one boiler is used for circulation, and one for steam cooking. The circulating boiler must, of course, be capable of good work, and the steam boiler has to be powerful. Yet this latter boiler may be only in use for two or three hours in the morning, and for the rest of the day the increased size of fire is a mere waste of fuel, and the water boiling furiously for no purpose. If it is at all possible to avoid using two boilers in one fire, it is much the best to do so.

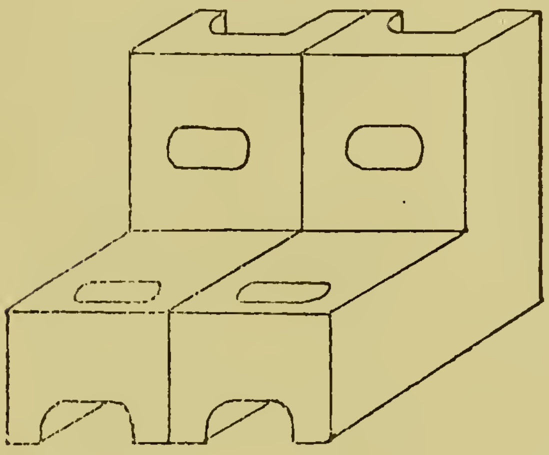

Fig. 315.

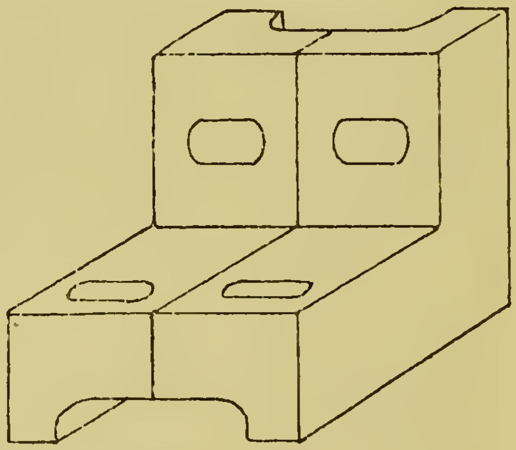

Fig. 316.

Coming within this subject is an arrangement for connecting and using two distinct boilers (say, in two different rooms) attached to one circulating apparatus; this is often resorted to, and is frequently of great convenience, particularly where the demand for hot water varies to any great extent during the day or in different seasons. In some institutions,—colleges for instance,—the quantity of warm water required for early bathing is frequently very large, and complaints then occur of the kitchen-range boiler being quite unequal to meet this excessive demand, although quite able to supply sufficient at other times in the day. The remedy, in this instance, would be to introduce an independent boiler ; but on this occasion it would be best to still retain the services of the range boiler, as it will not only aid the other materially, but it will permit of the independent boiler fire being let out when the demand has slackened. Or there are cases where a second range of smaller size exists in the kitchen or scullery, and if fitted with a circulating boiler it can be connected on to the apparatus which is worked by the large range, so that whichever is in use (or if both are at work) the supply of hot water does not cease.

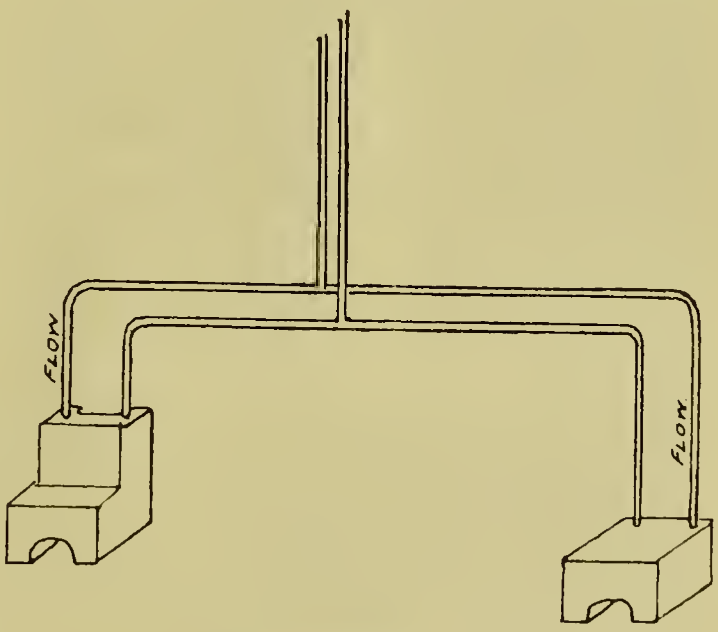

Fig. 317.

The usual way of connecting up the two boilers is as shown at Fig. 317, the flow pipe from each being joined at the nearest point, and the return pipes in a similar manner. If it is the cylinder system the pipes can be made to enter the cylinder from each side, or they can be jointed at the nearest point as just explained.

It is sometimes recommended under this arrangement to have a stop-cock inserted in each flow and return pipe (four in all), so that when one boiler is undergoing any repair or being cleaned, the stop-cocks in that pair of pipes can be closed, and so permit of the other fire being used to provide the customary hot water and cooking conveniences. This is certainly very convenient, but the introduction of stop-cocks into the main (primary) flow and return pipes is a most objectionable and sometimes disastrous practice. The least forgetfulness, or any conscious or unconscious trifling with the cocks, may lead to an accident, which is invariably fatal to any one who may be near.*

Sometimes twin boilers can be avoided by carrying two distinct sets of pipes from one boiler, but it will be clearly understood that these two systems must be fed by one cistern (or two cisterns on the same level), with the expansion pipes both carried to an equal height. Otherwise one will, of course, overflow the other the instant they are charged (unless an arrangement of stop-cocks is introduced, which, however, would not permit of the two systems being worked at one and the same time). An arrangement of this kind is of use when one or two small coils are to be heated, say, for an entrance-hall, from the kitchen boiler. It is then best, if it can be possibly managed, to take a flow and return service from the boiler, independent of the ordinary flow and return. This coil service *may* have stop-cocks, provided none are inserted in the other pair of pipes, and they will permit of shutting off the coils when the tank or cylinder is to be heated up quickly, or when the heat from the coils is not needed. This subject of coils in connection with kitchen-range boilers will be treated fully later on.

There is no objection to carrying more than one rising main (secondary flow) service from the top of the cylinder, if hot water is wanted at a distance in different directions, these various services being either brought back into one return or each having its own return to the cylinder. At one of the Hôtels Métropole, just erected, there are four 1½-inch secondary flow pipes, as water is wanted in great quantity in different parts of the building. The cylinder, however, is heated by steam, being made of copper and much like a multitubular boiler, but of course an independent boiler would heat it equally well if there was not steam to spare.

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* It is but a short time ago that a plumber—a practical man—lost his life through omitting to open these stop-cocks when testing a boiler, after having done some work which necessitated their being closed. He was killed instantaneously. A safety valve to each boiler would obviate this risk, of course.

IMPROVED AND OTHER SYSTEMS; PECULIARITIES NOTICED FROM EXPERIMENTS, AND THEIR RESULTS IN PRACTICE.

Perhaps one of the most interesting, as well as instructive, things that it is worth any one's while to erect, is a model hot water apparatus; its construction is simplicity itself, and to those who are at all interested it well repays the trouble. It would prove a most expensive undertaking to have the pipes specially made of iron, and the joints in themselves would possibly deter the most ardent. And what would prove most fatal to this arrangement is that, when erected, results could only be tested by feeling the different parts of the structure, and judging by the temperature outside, the same as in an ordinary house system.

If we make the reservoir of glass, and use a small-sized glass tube (say ½-inch) for the pipes, we then have an apparatus that will permit of its interior phenomena being *thoroughly* investigated, every peculiarity, however trivial its action, being instantly noticeable. Provided the proportions are about true, every reliance can be placed on it as a model of the actual working of a system. Amber dust, obtained by filing down a fragment of pipe mouthpiece (be sure it is amber), will render the movements of the water easily perceptible, as it is a material the particles of which will be found to remain perfectly still in still water, and only move as the particles of water propel them.* The glass tube can be jointed with rubber tubing.

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* Amber has very nearly the same specific gravity as water, and if amber dust is stirred into water there will be found, when it has come to rest, a great number of particles suspended in the water. Part of the dust will be found floating at the top, and can be taken off. Dust of moderately hard woods, as walnut and mahogany, answers with some success.

Perhaps one of the most useful results noticed in an apparatus of this kind, and which has proved to be a result of almost every day utility to many who have noticed it, is that water proceeds both up and down a flow pipe in equal volume when a draw-off tap connected to that pipe is opened. This is a perfectly natural result, for any work on hydrostatics shows us that in an apparatus of this kind the water cannot very well proceed from one direction only. Yet if a number of intelligent hot water fitters were asked from whence does the water come that flows out of a tap when it is opened, whether up the flow pipe from the boiler or down the flow pipe from the tank (on the tank system), the chances are that not one would say that the water proceeds equally half each way. The consequence is that numberless mistakes occur, some of them very perplexing to the uninitiated.

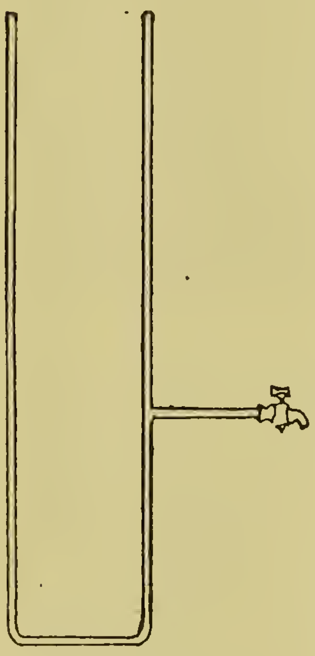

Fig. 318.

To more clearly explain the phenomena in question, if we erect a double tube, as at Fig. 318, and insert a draw-off tap in it at *any* point, as shown, and we then open the tap, what takes place? The water that issues from the tap does not wholly proceed from the pipe above the tap, neither does it wholly proceed from that portion of the pipe below. It will be found that as the water flows so will the level of water in the pipes be lowered exactly equal in each pipe, and this is a sure indication that the pressure both down and up is exactly equal, the same as if the lower part of the tube were taken away, as in Fig. 319. This will make it clear that we must expect water from both directions when a tap is opened anywhere in the circulating pipes of a hot water apparatus, as we have only to place a boiler at the lower end of the pipes (Fig. 318) and a reservoir at the top extremity to have a tank apparatus almost complete.

The commonest fault arising from an ignorance of this fact is the "returning" of a draw-off service on a tank apparatus. The draw-off service, of course, proceeds from the flow pipe, and is carried back and connected into the return, and the effect is that the water does not lie stagnant, as it does in a single pipe, for the hot water then circulates right up to the tap, or nearly so. Everything is satisfactory up to this point, but immediately the tap is opened a partial failure manifests itself, for water will instantly proceed in equal quantities from both flow and return pipes, and as it is the exception rather than the rule for the return pipe to be hot, the water that issues from the tap will not always be of a satisfactory temperature, certainly not as hot as it might or should be. Should the whole apparatus be full of hot water so that the contents of the return pipe are nearly as hot as the flow, then, of course, the water drawn off will be of a satisfactory heat. But even this satisfaction would be short lived, for the instant water commences to flow from the tap a corresponding volume of cold water enters the tank and quickly finds its way down the return pipe.

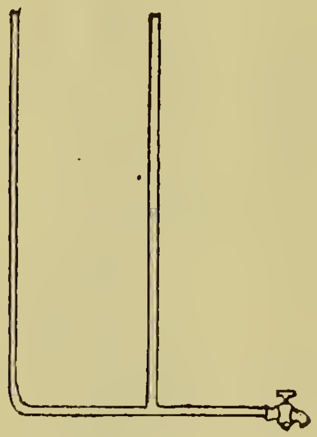
Fig. 319.

Observation of this action of water proceeding from all directions to an open tap has led to the rising main of the cylinder system being returned and connected into the cylinder at a high point (as explained on p. 447), so that although the water makes its way up both pipes when a tap is turned on, yet as both proceed from the upper part of the cylinder no ill result whatever ensues. It was but a short time ago, and is very often now, the practice to return the rising main into the bottom of the cylinder or into the primary return, and many an apparatus has been cured of its inefficiency or been greatly improved by the mere alteration of this detail.

The discussion of this particular action may not strike every one as being worthy of the importance that is being attached to it, but in practice it will be found that there is no effect which requires to be so continually under consideration when a problem in this work presents itself, and a knowledge of it is of the utmost value in a practical sense.

It should be mentioned that the question of the friction or resistance that water experiences in flowing through pipes has not been overlooked, but it makes such a trifling difference to this particular subject that it is scarcely worth consideration. Of course, if a tap were so situated that in one direction the water had only to flow a few feet, and in the other direction a hundred feet, a marked difference would be noted, but so great an inequality seldom occurs.

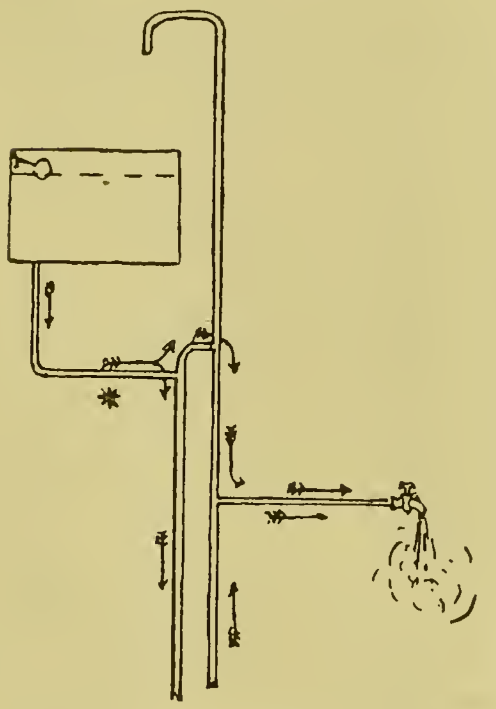

Fig. 320.

Another question intimately connected with this subject is whether the cold-supply service of the cylinder system could by any means be shortened by taking it into the secondary return or elsewhere, and the study of the results made visible in a glass apparatus has gone far towards settling the question.

There · has always been the objection of having to provide three pipes (rising main, return, and cold supply) in a complete cylinder apparatus, against the customary two of the tank system, and this has led to various attempts being made to make one pipe answer the double purpose of secondary return and cold supply to the cylinder. The majority of these attempts, however, have been failures, or else so limited in their success as to be held in suspicion as unreliable.

If we take the cold supply direct into the secondary return, as Fig. 320, we shall have the worst possible results, especially with the taps at the top of the house, for immediately the taps are opened, a flow of cold water will set in direct from the cistern to the tap, as indicated by the arrows.

In this instance the friction element will be against the good results, as considerably less resistance of this character will be felt by the water that passes direct from the cistern, than by the proportion of the water that comes *up* the rising main, as this latter quantity has to pass down the house and through the cylinder before it can come up to the tap. An attempt was made to prevent the cold water passing to the tap by putting a deep dip in the pipe where marked ∗ on the illustration, but this had no good effect; in fact, the suggestion was somewhat absurd.

The only means at present known of overcoming the difficulty is to insert a "stop-back" valve in the circulation. These valves are made expressly to regulate a flow of water so that it may travel freely in one direction, but should it from any cause attempt to travel the opposite way it is instantly checked. The valve is by no means a modern idea, as it is used in various forms for different purposes, particularly in sewage work, &c., but its application to hot water work is somewhat recent and by no means general yet.

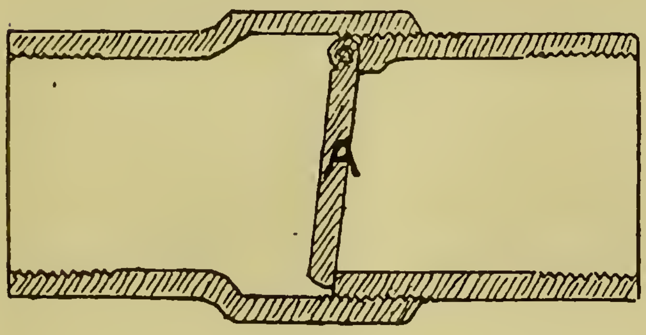

Fig. 321.

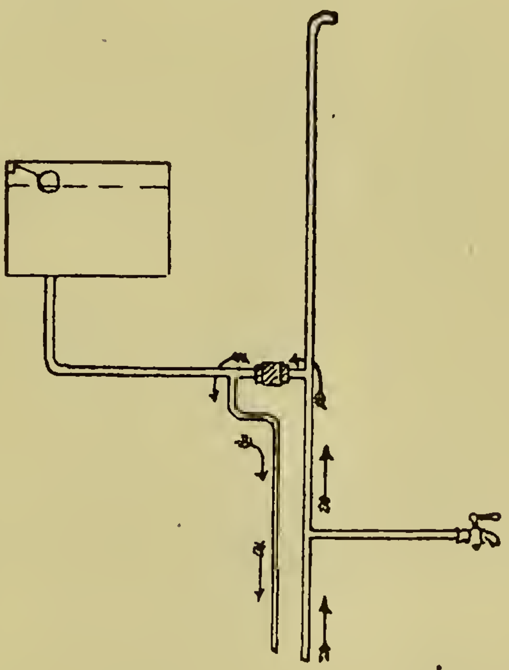

Fig. 322.

Fig. 321 shows in section a valve of this sort, of simple construction, and the only particular care needed in its manufacture is to have the flap A loosely hinged or jointed. In action the flow of water in one direction lifts the flap readily, but in the other direction it tends to close the flap tight.

The flap shuts on to a turned surface so that it is practically water-tight.

In fixing one of these valves it should be placed somewhere in a horizontal position between the point where the cold supply enters the return pipe and the point where the return is branched from the rising main, as Fig. 322, so that when the water is circulating it passes the valve, as indicated by the arrows. When a tap is opened the valve is closed by the approach of the cold water from the direction of the cold water cistern, and the whole of the water drawn has, perforce, to come up the rising main from the cylinder, while the corresponding volume of cold water passes down the secondary return.

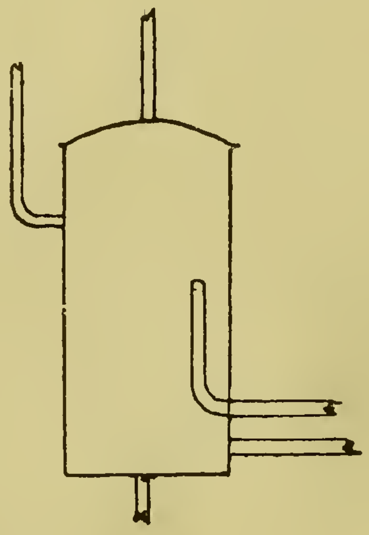

Fig. 323.

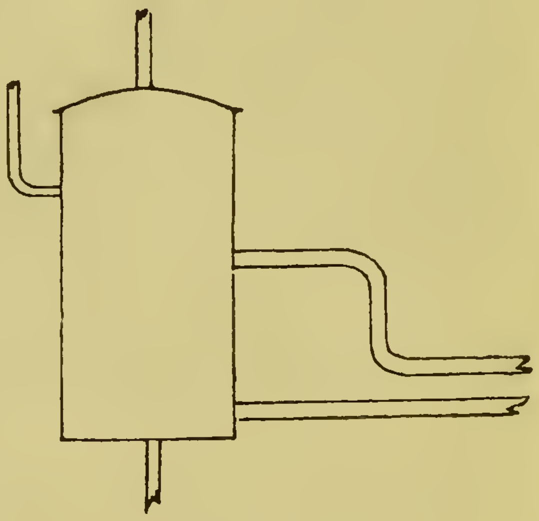

Fig. 324.

When the secondary return is made to answer this twofold purpose, it should not be connected high up in the cylinder, but near or into the bottom as a cold supply.

It has been shown in some of the preceding illustrations that the primary flow pipe from the boiler is connected into the cylinder about 8 inches up, and that there is a piece of pipe (attached by an elbow) carried up inside, so that this flow really terminates a little more than half the way up, as Fig. 323. This may appear to many to be rather an unnecessary and peculiar arrangement, which it really is, as the same purpose will be attained by letting the flow enter the side of the cylinder half the way up, and so make the standpipe inside unnecessary, as Fig. 324.

The cost of fitting in either instance is about the same, but by the latter method a benefit is experienced by lessened trouble, as should the cylinder have a removable top and no manlid, it will be found a most difficult task to attach the elbow and pipe inside, particularly if the cylinder is a high one. It matters not where a cylinder is purchased, if flanges for flow and return are ordered they will be put *both* within 9 inches of the bottom. Yet the poorest of hot water fitters knows that a primary flow pipe should always terminate at least half-way up a reservoir of either description. Therefore, if care is taken to order sufficient flanges to be affixed to the cylinder in their proper places, a saving in cost may be effected also, as there is then no special need for a manlid or removable top, and this makes an average difference of about 6*s*. (in the price of the reservoir), an economy worth practising for the little trouble it entails.

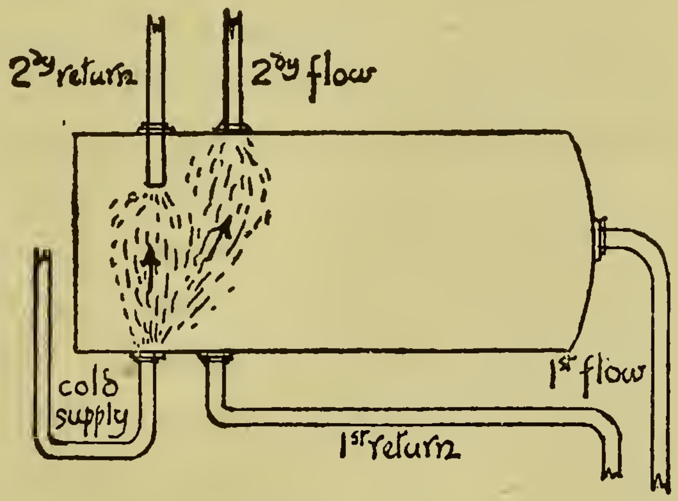

Fig. 325.

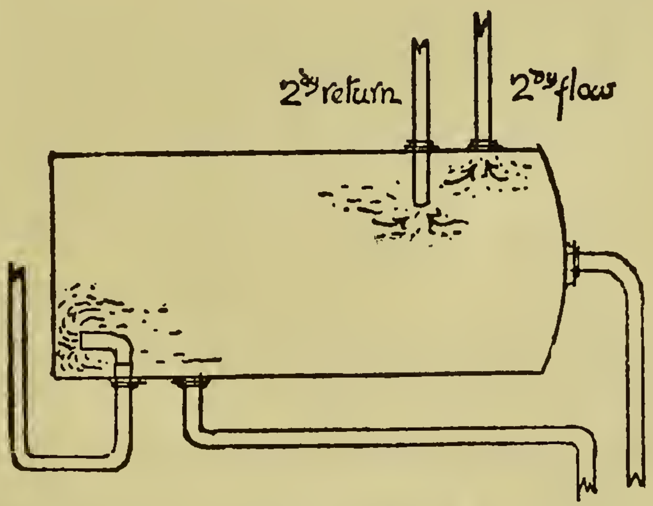

Fig. 326.

It is very often necessary to fix the cylinder horizontally, that is, lying on its side. The connections have, in this case, to be regulated by the effects already dwelt upon, but some new features are introduced that may bring about ill results. Take, for instance, Fig. 325; this represents a cylinder fixed on its side, with all connections made properly as to the various heights they should have, but very bad results are obtained. These are due to the position occupied by the cold supply connection in its relation to the rising main, from which the draw-off services are taken. It has been explained more than once that there is the closest possible connection between the outflow of hot water from a tap, and the instantaneous inflow of cold water into a cylinder or tank. In this case the instant a tap on the rising main is opened, the inflowing cold water takes a straight passage to the rising main (secondary flow and return), as shown by the dotted lines in the illustration, preventing more than a small quantity of hot water being drawn. Fig. 326 shows a cylinder with the connections so arranged that this ill-effect would not be experienced, as shown by the dotted lines.

There can occasionally be found an apparatus with the cylinder connected-up as at Fig. 327, a method that can by no means be condemned, for it answers a useful purpose in giving hot water in the upper part of the apparatus a little quicker after first lighting the fire. There is (as will be seen) a clear way for some of the water to circulate from the primary to the secondary flow without passing through the cylinder. In practice it is found that by this method about one-half passes each way, but, of course, the half that passes into the cylinder loses its heat almost instantly until the apparatus (or upper part of the cylinder) is charged with hot water. Consequently, water of a high temperature will be obtained in the upper pipes quicker by this arrangement, but it will only be in small quantity.

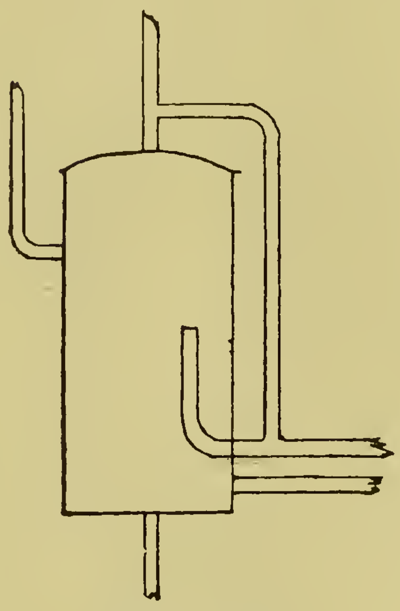

Fig. 327.

Occasionally, advocates for carrying the primary flow pipe direct from the boiler to the highest point in the house (constituting it both primary and secondary flow) and having the return pipes connected into the cylinder only, as Fig. 328, are to be met with. This is a practice that should only be resorted to on special occasions, as we have to bear in mind that the store of hot water in the cylinder is added to but very little, except by the pipe which has been all round the house, and probably lost the major portion of its heat.

By this means, however, hot water is obtained at the taps very quickly, though it is a late hour before there is any in storage of a high temperature. As an instance of its successful application, might be mentioned the case of a large residence where trouble had always been experienced in obtaining hot water at the bath in the early morning. The bath-room was situated a great distance from the kitchen (160 feet run of pipe), and considerable time was needed with an ordinary kitchen-range boiler to get really hot water at this point, it having first to pass through the cylinder. A change was therefore effected, as Fig. 328, and the trouble was at an end, as the hot water reached the bath-room in much less time. As the pipe was of great length, it held enough in itself for one bath without depending upon the reservoir; but this successful instance must not be construed into a recommendation of the method described.

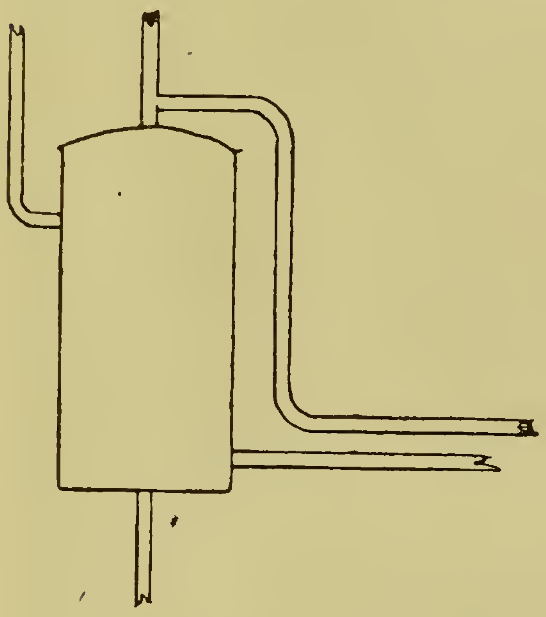
Fig. 328.

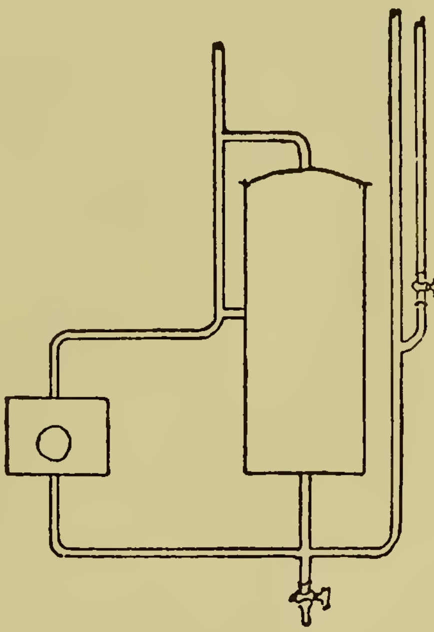
Fig. 329.

Another arrangement of connecting-up the pipes to the cylinder and the boiler, is as Fig. 329, known as "Dyer's system." With this apparatus we must content ourselves with a description only, as it does not come within the province of these papers to discuss the merits or demerits of individual systems. It will be noticed that in this the primary flow has communication with the secondary flow, as already explained. The cold supply is carried down and connected into the cylinder at the bottom, and is continued and connected into the boiler at the bottom also, and the secondary return is connected into the cold supply at a low point as shown.

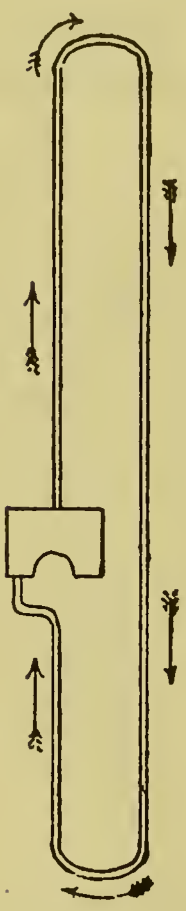

Fig. 330.

A prevailing notion amongst the majority of hot water fitters, particularly with some of the stubborn ones, who have been faithfully practising for years what they were taught in their boyhood, is that on no account must the flow pipe descend anywhere in its course, nor must any circulating pipe descend below the boiler. Nor must, in fact, any pipe take a course that is irregular with the ascent of the flow pipe and descent of the return, which has become traditional, and from which a departure would be looked upon as an offence against all accepted principles.

In theory, several of the best authorities agree that under what we may term common circumstances a circulation can be effected about three-fourths the distance below the boiler that the circulation extends above it, as Fig. 330, and the result is arrived at as follows :—First, it is necessary to impress upon the mind that the circulation of water is brought about by the fact that cold water is heavier than hot, *not* that hot water is lighter than cold. This is a distinction with a considerable difference, so far as it affects this argument, for it can be seen plainly that heated water has no inclination to rise unless it is lifted or pushed, so to speak, by a superior force. If we take a vessel of warm water the contents will not rise out of it, but if we take an exactly equal quantity, by measure, of hot water and cold water, and place one in each pan of a pair of scales, we should then find that the pan of hot water would rise for the simple reason that the superior gravity of the cold water caused it to do so. Now, in an apparatus as at Fig. 330, when heat is applied to the boiler its contents become rarefied, or lightened, and a circulation will set in as indicated by the arrows. If, in a short time, we apply the hand to the pipe, we shall find that, starting from the top of the boiler, the pipe is of a less and less temperature as we pass round it towards the bottom of the boiler (in the direction indicated by the arrows). The difference in temperature may be due to two causes, firstly, loss of heat by radiation from the pipes, which, of course, is greater the further we get from the starting-point; and, secondly, the boiler may not have had time to heat up the whole of the contents of the apparatus to boiling-point (for we cannot have a uniform heat everywhere in a circulating apparatus until this temperature is reached, which seldom happens). Consequently this makes plain to us that the pipe which ascends from the bottom of the apparatus up into the boiler has the coldest and heaviest water in it, and this is the obstacle that more or less interferes with a good circulation being effected below a boiler. If the lower part of the apparatus extends a greater distance below the boiler than the upper part extends above it, we must understand that no circulation will take place, and although this is not strictly correct, it cannot be practically applied in hot water supply work, and, what is more, it is but very rarely required.

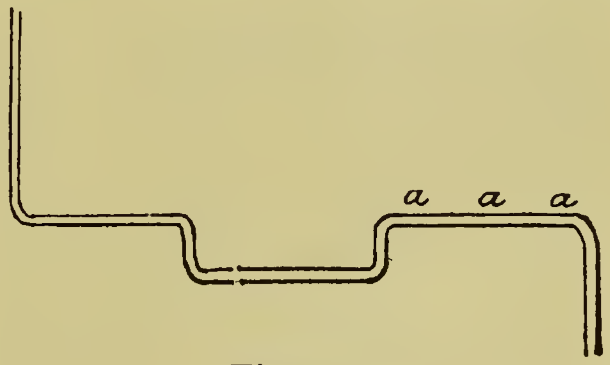

Fig. 331.

It very frequently happens that a fitter would find it very convenient if he could make a dip in his flow (and return) pipe, as Fig. 331, for instance; but, according to all accepted ideas, it would possibly ruin the apparatus; yet this is not the case, although it might give a good deal of trouble. The trouble experienced in this instance is the difficulty in dislodging the air from the upper part of the service, *a a a*, for it will be found that in such a place the air will remain with the greatest persistency, and to remove it effectually an air-cock would have to be provided for periodical use. Although we may allow the air to escape when first charging the apparatus, it does not wholly overcome the difficulty, as there is always a certain amount of air carried into the pipes with the water, and this will collect at any such point and require removing regularly, which we cannot expect servants to do. If it was not for the collection of air at this point, there would be no objection whatever to dipping the flow pipe in the manner indicated, as it would be found that a dip of a few inches only would make no appreciable difference in the circulation.

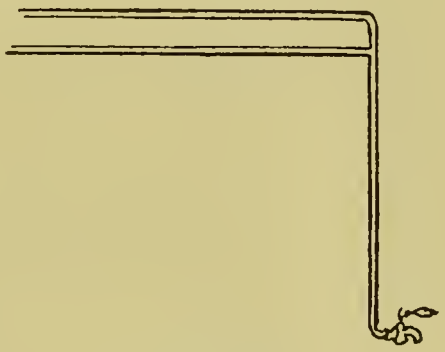
Fig. 332.

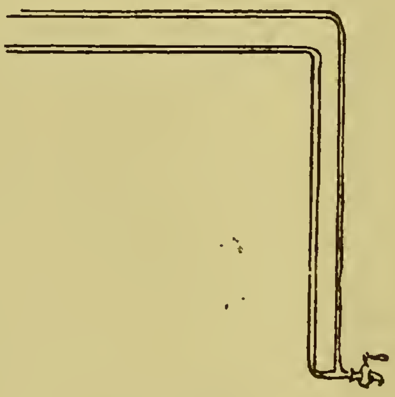
Fig. 333.

An instance of a descent in circulating pipes to which no objection can be raised is when it becomes desirable to carry a returned draw-off service close to the tap. It has been the general practice when returning draw-off services to connect the returned portion at the point where the pipe turns down to the tap, as Fig. 332, leaving some 6 or 8 feet of single pipe in which the water lies stagnant. This in most instances is not very objectionable, but, should it be desired, the pipe may be returned from a point close to the tap, as Fig. 333, and the circulation under this arrangement will be very good; or where the pipe rises to the tap, as Fig. 334, the circulation will be found quite perfect. In the case of a lavatory basin, it is always a satisfaction to find hot water issuing *immediately* a tap is opened; the majority of these have but small taps, and annoyance is always experienced here if any cold water has to be drawn off before the hot arrives.

As a general rule, there is only one objection to dipping the circulating pipes (provided the dip is not a very deep one), which is, that it probably leaves some portion of the pipes as at Fig. 331, and the dislodgment of the confined air will give infinite trouble. On this account, any plan of carrying the pipes in irregular directions requires considerable thought before being put in practice, for it must be borne in mind that a collection of air in pipes will quite impair the efficiency of the apparatus and bring about noises and erratic results. In a heating apparatus, air-cocks for releasing confined or collected air figure very prominently, as they require fairly regular use; but a heating system is commonly under the care of some one who has a knowledge of the air-cocks, and their use is anticipated.

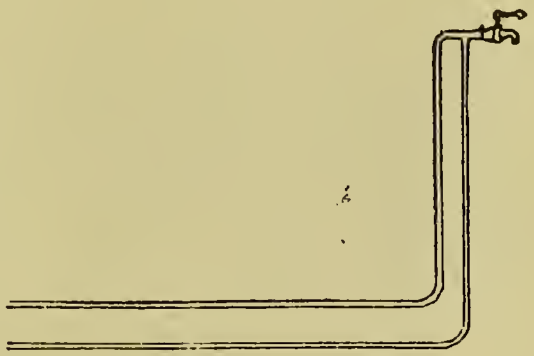

Fig. 334.

Attention may here be drawn to a feature in the cylinder system which has not been mentioned before, but which is of considerable importance in rendering general good results. This is the insertion of a stop-cock in the secondary return, which may be closed at night to stop the circulation and so retain the store of warm water in the cylinder (which is usually in a warm position). The contents of the cylinder can then be relied upon to provide a tepid bath before the fire is lighted in the morning. If the upper circulation is not stopped, we have the water travelling around the house, dissipating its heat in all directions to no purpose, as the circulation will not cease of its own accord until the water is cold.

The best position for this tap is in the kitchen or somewhere where it can be easily used, as Fig. 335; no harm can ensue, as, should it be left closed, it only converts the secondary flow into an ordinary single rising main, and the effect is that a quantity of cold water would have to be drawn before hot was obtained in the morning. If the cock has to be put near a ceiling it can have a cross-key with cords or chains, as Fig. 336.

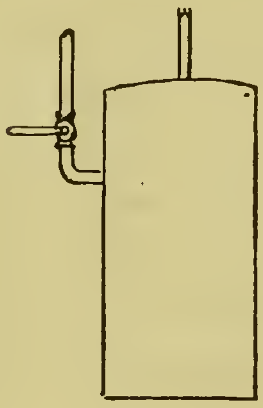

Fig. 335.

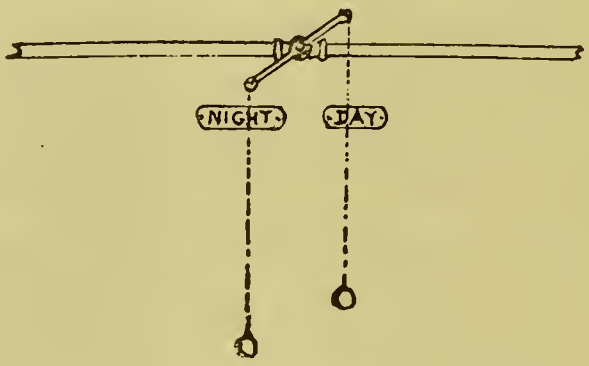

Fig. 336.

COILS AND COIL SERVICES.

The attachment of a small quantity of hot water pipes or a coil or radiator to a supply apparatus is much in vogue, but it is really not a practice that can be recommended very strongly unless special circumstances make it necessary. In the first place, a coil service and a supply service for draw-off purposes are directly at variance with each other in the objects that they are intended to attain. With the former the sole aim and purpose is to radiate, dissipate, and transfer the heat from the water to the air, whereas with the latter every effort is usually made to conserve the heat within the pipes, so that it may all be had with the water from the taps, and not to diffuse it with a proportionate reduction in the temperature of the water. Consequently, if a heating appliance of any description is connected on to an existing apparatus, a reduction in the quantity or the temperature of the hot water must be anticipated. If we include such an appliance in a new apparatus, we should, of course, put a boiler of a power more than is just sufficient for the taps only.

It is very commonly desired to heat a small greenhouse or conservatory by one or two pipes heated from the kitchen boiler, and this arrangement is just as commonly carried into effect; but it has a most fatal objection, for when the heat is most needed, in the early morning hours, the fire is out and the water cool. This objection is not so noticeable with a coil in the house, as the loss of heat brings about no serious harm and no particular inconvenience at night, when the occupants are at rest. If, however, the coil was in connection with a stove that kept the fire going all night, a great deal of comfort would be felt from the warm temperature in the early morning, when the cold is greatest and felt the most.

If the kitchen range has a convertible open and close fire, this goes far towards overcoming the difficulty just referred to, as an open fire, if fed the last thing at night, will frequently remain burning until morning, and, although the combustion is slow, it keeps up the temperature very well, a small fire being capable of this when no water is being drawn off.

In concluding the objections to the arrangement now under discussion, it should be mentioned that a boiler which is sufficiently powerful to give a good supply of hot water and satisfactorily work the heating appliance in winter will probably prove a source of annoyance in the summer by furiously overdoing its work, the coils being then shut off and the demand for hot water considerably diminished.

The oldest form of coil is that having box ends, as, in fact, many are made now, but the joints between the pipes and the box ends were made and secured by a rust, or a composition joint which was a great source of trouble to make up. These rigid joints did not do very well, as the expansion and contraction brought about occasional leakages, and under the best of circumstances, the erection was abnormally ugly, requiring an expensive casing solely to hide it. This casing itself introduced two obstacles to the success of the coil, the first being that it obstructed and absorbed a deal of heat. Secondly, and worse, it made it difficult to keep the coil clean. It is surprising what a preventive of heat-radiation a coating of dust is, it being composed chiefly of poor conductors of heat (minute particles of wool, fibre, straw-like materials and stone grit).

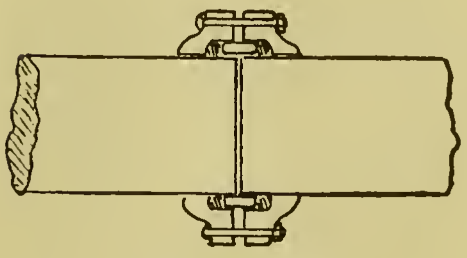
Fig. 337.

More recently two or three forms of expansive joints (the packing medium being a rubber ring or collar) have come into use, and are a decided improvement, as, although costing a little more, the joint does not fail, and the labour of erection is reduced to a minimum. Fig. 337 (in section) is one of the joints as applied to two lengths of pipe. It will be noticed that the pipes may have perfectly plain ends, no sockets being needed; and if the pipe ends are a little rough or irregular, a good joint can still be made. Fig. 338 shows a coil made up with this joint connecting the pipes to the box ends.

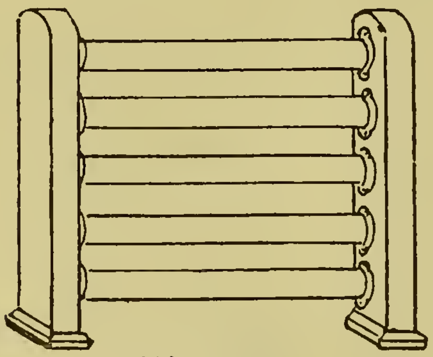
Fig. 338.

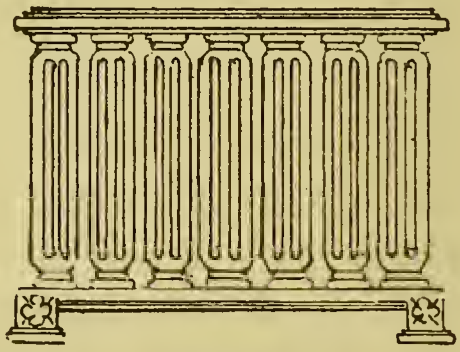
Fig. 339.

A more recent introduction, which is very suitable for houses, as no casing or other device for hiding it is necessary, is termed a "radiator" (Fig. 339).* These are now being made in various designs and forms by different manufacturers, and as they can be coloured to match the surrounding decorations their appearance need not be objectionable.

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* Radiators are fully described in the heating section of this book, pp. 294 to 307.

The majority of these radiators have the pipes in a vertical position, and an object retained in view by the manufacturers is to give as large a heating surface as possible with the smallest quantity of water, so as to get quick results. Of course, they just as quickly grow cold when the fire is out, but this is not a serious matter in a residence where the kitchen fire is alight from 7 a.m. to 10.30 p.m. in winter. The small quantity of water is an advantage, as a coil of ordinary pipes which holds so much water is like attaching a second reservoir to an apparatus, and it greatly imperils the efficiency of the boiler, besides taking a great deal of time to heat.

As a general rule, it may be considered that two medium sized radiators is as much as ever should be attached to a domestic supply apparatus. To attach more than this will only be at the risk of rendering the supply of hot water at the taps inadequate in temperature, and it is only when a boiler is more powerful than is necessary for the supply of water drawn off that this can be done.

There has been some controversy as to which gives the best results—a coil or radiator of vertical pipes, or of horizontal pipes. From experiments made it is found that the water will circulate through each at about the same speed, but with horizontal pipes there will be found a difference in temperature between the top and bottom pipes, whereas with the vertical pipes the circulation is regular through all pipes, and it is quite the exception for one pipe to heat differently to the others, supposing no obstruction exists. But it has to be pointed out that with vertical pipes, if air accumulates and prevents the pipes filling right up, the circulation will be checked, but at the same time this only indicates that the air-cock wants opening, which instantly remedies the trouble. A strong point in favour of vertical pipe coils is that they do not get thickly coated with dust.

There are various ways of connecting these appliances to the circulating pipes; some on to the flow pipe only, some on to the return (the secondary return to a cylinder, not the return of a tank system), and some on to both flow and return.

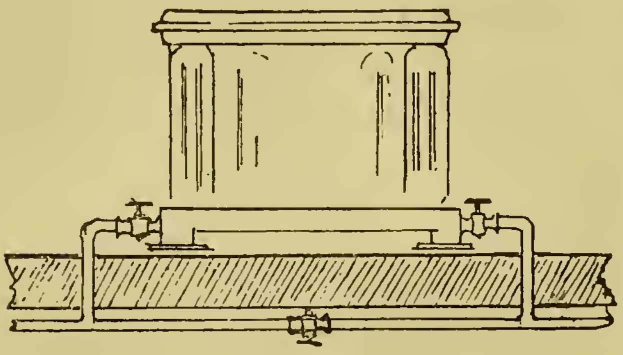

Fig. 340.

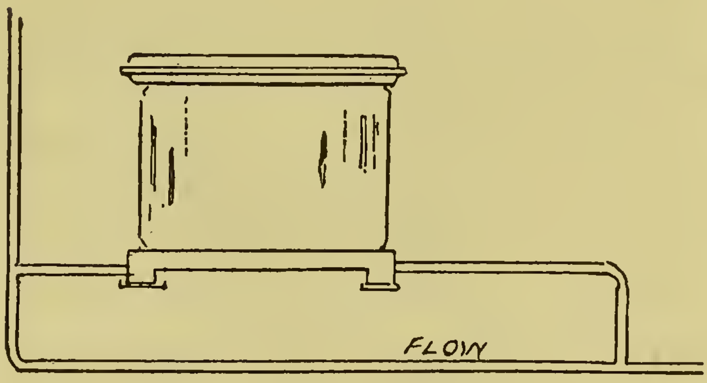

Fig. 341.

To commence with the first arrangement, Fig. 340 illustrates a radiator connected to a flow pipe with a stop-cock beneath to divert the whole or part of the water through the coil as required. This is the plan most generally adopted, but the stop-cock in the flow pipe between the radiator connections is quite unnecessary. The introduction of this stop-cock has been upon the assumption that the heated water would probably pass by the radiator if a free way existed; that the water of the radiator would remain stationary unless compelled to move by what force the circulation of the whole apparatus could bring to bear. In practice, however, it will be found that a body of cold water cannot be made to rest over a pipe or vessel containing hot water, if there is open communication between them. In the instance under discussion, hot water will be found to pass into and through the radiator in the most satisfactory way without a stop-cock to divert it. The stop-cocks at the sides of the coil are for wholly stopping off the circulation when not required. Two stop-cocks are necessary if the coil is required to be quite cold in summer. The coil can then be provided with a tap to empty it and prevent its rusting when not in use.

Sometimes the connections can be arranged as at Fig. 341, by which a little better results are obtained, but the gain is so slight that it is not worth while going to great trouble to effect it.

When it is desired to connect the coil with both flow and return, it is done in a similar manner to a returned draw-off service, as at Fig. 342 or Fig. 343.

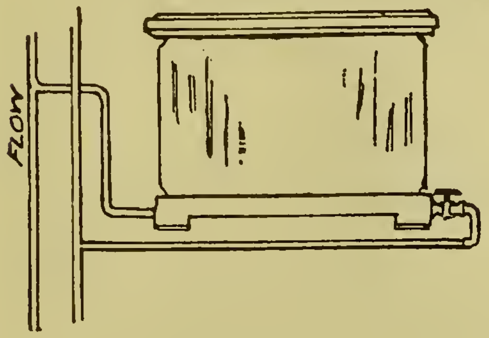

Fig. 342.

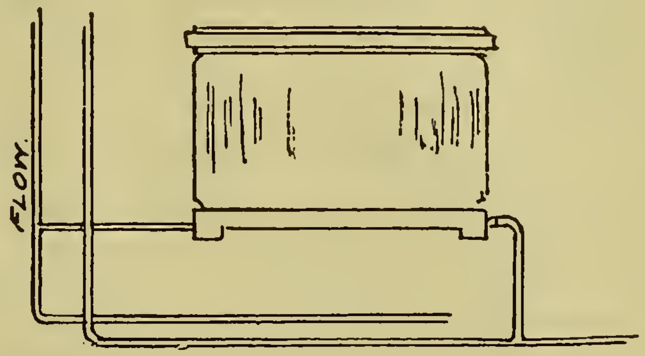

Fig. 343.

If a coil is attached to the secondary return of a cylinder apparatus, it can be arranged as at Fig. 344, but in this case the cocks can be adjusted to allow the whole of the current through the coil, supposing there are no draw-off taps past it—i.e. between the coil and the cylinder—at E, for instance.

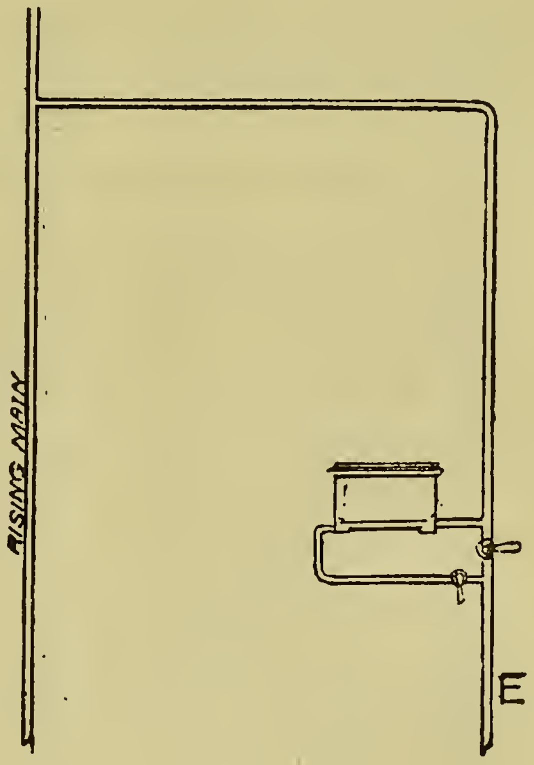

Fig. 344.

It is usually found that if *two* stop-cocks are not provided for shutting off the coil (one in the pipe *to* it, and one in the pipe *from* it) the coil will not remain quite cold, and although its temperature will not be high, the warmth is usually objected to in the hot summer months, when the least artificial heat is considered intolerable. It is found in the majority of cases that one stop-cock, although closed, does not wholly prevent a feeble circulation setting in up the open pipe, although this is generally aggravated by the stop-cock being placed in the wrong position. If the cock is placed in the pipe that leaves the coil, as shown at Fig. 342, the coil will not heat, except to a trifling extent, as we have to remember that, although a slow circulation will set in up a single pipe, it is next to impossible for it to take place in a directly descending one.

The radiators referred to are supplied by the makers completely fitted, so that the connection of flow and return pipes is all that is needed. This makes an agreeable improvement upon the old pattern coils, which had to have all the pipes fitted and jointed on the premises. This convenience is paid for perhaps in the slightly increased cost of radiators over plain coils.

An instance in which coils were attached to a supply apparatus, and to which no objection could be raised, was in a residence only occupied during the summer months. In this case the coils did not come into use during the occupation, so that the supply of water for domestic purposes was not interfered with, but when the house was left in charge of two servants during the winter very little hot water was required to be drawn off, and the coils had practically the full benefit of the fire. There was one coil placed in each of five bedrooms for the purpose of keeping them aired, which they very effectually did. In an instance such as this, and whenever it is at all possible, it is best to take a distinct service to the coils, not in any way connected with the flow and return of the supply apparatus, as this in the majority of cases will save putting stop-cocks in awkward places. If two distinct services are taken from the boiler they both start about equally, and should the coil service rob the supply then there is no objection to putting a stop-cock in this (coil) service, to check, adjust, or stop the circulation in that direction. If a distinct flow and return is not practicable, perhaps the flow pipe can be so run, and the return branched into the other return, but in either case it is desirable to have stop-cocks in both the heating service pipes to totally prevent circulation. By this means the coils and coil services can be emptied (by a cock provided for the purpose) in the summer months, to save the extensive rusting that would go on.

There remain to be mentioned two small heating appliances that can, without any objection, be attached to a supply apparatus, as they need but very little boiler power to operate them, and are articles of great utility in many instances. The first is a coil for heating a linen-closet (or, in other words, airing linen in a cupboard or closet). This is usually made up of $\frac{3}{4}$ or 1-inch ordinary wrought pipe, as Fig. 345, and six or eight pipes, 3 feet long, are sufficient for a large-sized cupboard, say 9 feet high, 6 feet broad, and 3 feet deep.

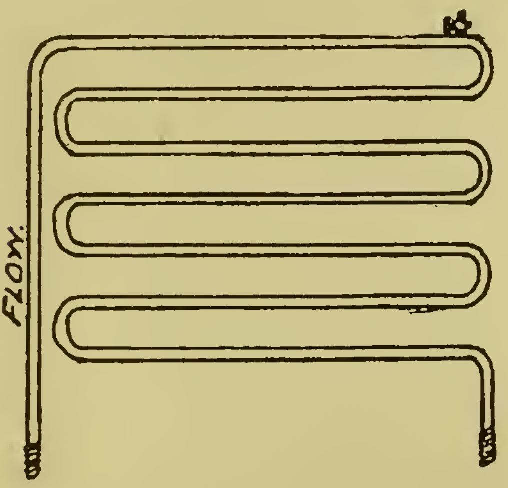

Fig. 345.

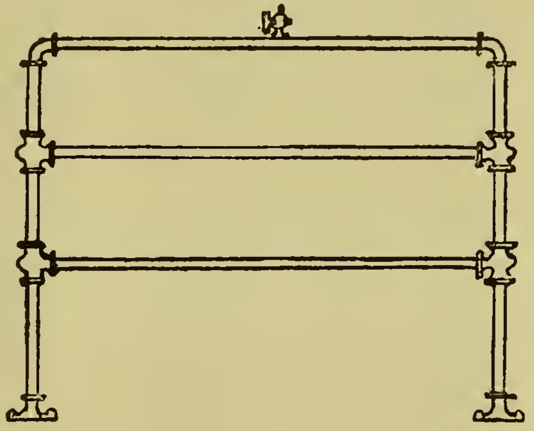

Fig. 346.

This coil does not particularly need any stop-cocks, as it is generally used all the year round.

The other appliance to be mentioned is a towel-rail made of tube (decorated in colours or nickel-plated), as Fig. 346. This serves the purpose of drying and airing towels, and if it is severe weather the warmth both to the towels and in the dressing or bath room is agreeable. This does not always need stop-cocks.

One very essential feature in any description of coil or radiator is an air-cock or tube for giving free escape to the air with which the apparatus is charged before it is filled with water; and also to discharge the air that is perpetually accumulating in every description of hot-water apparatus. These air-vents require to be fixed at the highest point on every coil, as air being so much lighter than water it is always to be found in the extreme highest positions.

The objection urged against an air-cock is, that it wants regular attention (once or twice a month), which is thought to make it unsuited for domestic purposes. The alternative is to have an air-pipe, which being open at the end, gives free discharge to the air as fast as it accumulates, and requires no attention. An air-pipe is not always convenient, for should there be a coil situated on the ground-floor, and the general apparatus terminates at the top of the house, then the air-pipe must be carried up to the top also, or it will overflow; it is, in fact, a secondary expansion pipe. If air-pipes are used, they require to be just as many as air-cocks; one air-pipe may be branched into another, but on no account must an air-pipe *descend* anywhere; in fact they should not be carried horizontally, but ascending in a greater or less degree everywhere from beginning to end.

If a single coil is attached to a supply apparatus upon the tank principle it can either be connected to the flow pipe wholly or to the flow and return, as already explained; but with an apparatus upon the cylinder system we are better situated as regards this, as we can connect it to the flow (secondary), or flow and return (secondary), or to the return only (secondary). This latter arrangement is the best by far, but is not applicable with the tank system, as with this latter the return takes a great time to get hot, and when it is so it is continually being cooled whenever a tap is opened and cold water enters the tank.

In connecting a coil to the secondary return of a cylinder apparatus we gain an advantage in only using water that has practically done its work, it having passed all the draw-off services and only having to pass through the coil on its way back into the cylinder. This is worth every consideration, for if a hot water apparatus is designed to supply *hot* water, there should be no obstacles or impediments placed in the way of its doing the work thoroughly. To place a coil between two draw-off services means, as a matter of course, that the tap on one side will have hot water some time before the one on the further side, and if this one on the further side is of the least importance the coil will prove a source of annoyance to this extent. If the coil is placed in the return beyond the taps, the whole of the return water (which in a cylinder apparatus is very hot) can be made to pass through it, but a means of cutting it out must be provided for the hot weather.

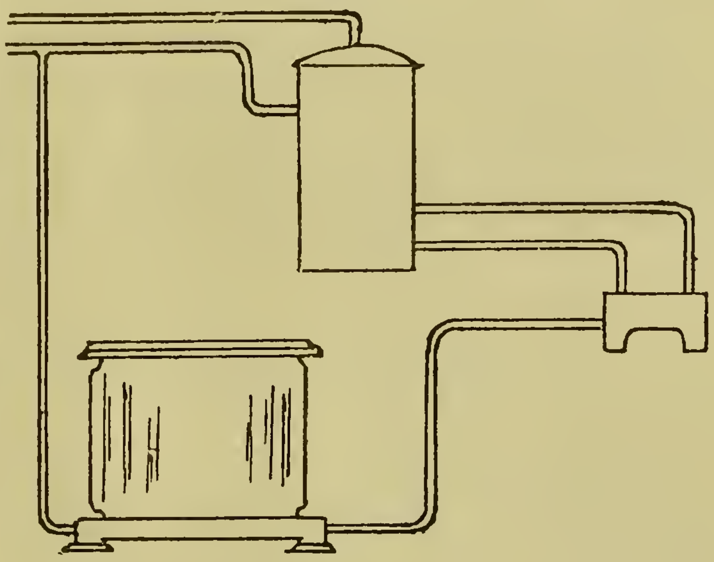

Fig. 347.

In many of our suburban residences, it occurs that the kitchen is on the same floor as the entrance hall, and it is desired to place a radiator in this hall (one of the most efficient places for such a thing) with a view to warm some of the cold air that is perpetually pouring in there. A difficulty arises in the fact that if we place the radiator on the floor its connections will be below the boiler, a difficulty commonly supposed to be insurmountable, but such is not exactly the case, for we have already shown that in the usual way a pipe may descend (dip) and ascend to a certain extent, and it is so in this case.

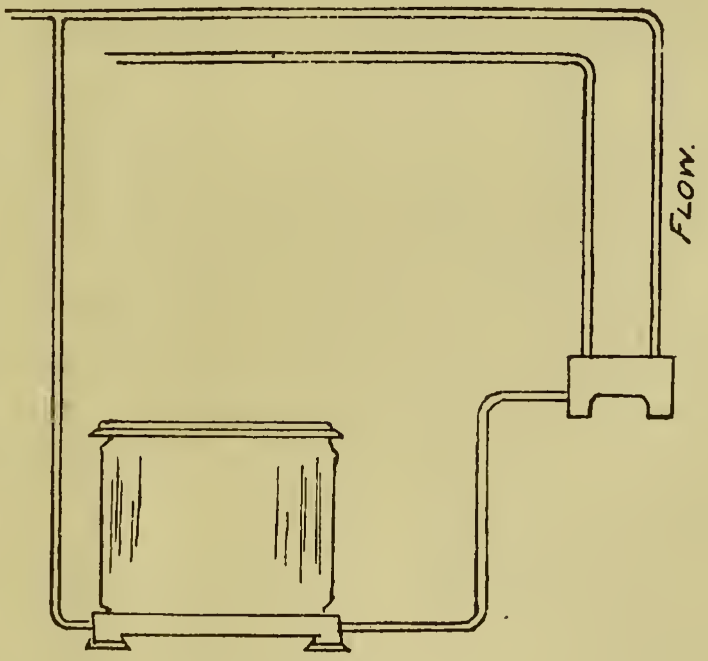

Fig. 348.

It is not necessary to deal with the theory that supports this suggestion here; the subject is fully treated in the chapter devoted to Circulation, pages 112 to 117, and also on page 486. In practice it will be found that this arrangement is permissible, and will give fairly good results, sufficient to prevent its being deemed a non-success.

It is necessary, to effect this, that the general apparatus extend up two or three floors, as usual, in which case it may be connected up as at Fig. 347 or Fig. 348, illustrating the cylinder and tank systems respectively.

FAULTS AND SOURCES OF ANNOYANCE.

To enumerate all the faults that may meet even a single individual's experience would occupy a great deal of space, but there are some of a very common character that it may be profitable to call attention to and describe. One is the connection of a draw-off service (or services) to the return pipe instead of the flow. This, although of frequent occurrence, can only be the work of an utterly ignorant or careless man, or one who has been accustomed to heating work in which the return pipe commonly has services connected to it. This fault is usually recognised by one tap yielding water of a very different temperature to the others, but if all taps should be from the return pipe a difficulty may be experienced in judging whether the boiler or other part of the apparatus is at fault, unless the pipes are all exposed so that the error in connection is obvious.

Another, and only too frequent, cause of failure is a boiler of insufficient power. This can usually be detected in a measure by the fact that hot water is only obtained some hours after the fire is lighted, or only some time after the early demand has temporarily ceased—say, between breakfast and luncheon hour. There are great numbers of ranges condemned on this account, as but few range-makers even now seem to comprehend that an efficient supply of hot water is as essential as efficient cooking facilities, and the most miserable boilers are often provided with what otherwise may be first-class ranges. The only remedy is to introduce a good boot boiler, or an independent boiler if needed.

Sometimes the work of a boiler is rendered next to futile by reason of the pipes being exposed to such an extent as to cause a serious loss of heat by radiation. This happens when the pipes are carried along cold galleries or stone corridors, or if they are carried in vertical casings which are not packed or filled with some poor conductor of heat (as has been already explained). What, perhaps, is the most frequent cause of this trouble, is the tank being situated and exposed in a roof where it is robbed of its heat as fast as it is possible to do so.

Another frequent cause of trouble is omitting to terminate the return pipe in the boiler at a lower point than the flow, although every care is exercised to terminate the flow at a higher point than the return in the tank. This arrangement is adopted by many, who profess that it gives equally good results as making the return lower than the flow in the boiler; and, certainly, if the apparatus is once started right and kept going, without cessation, no trouble would afterwards arise. But when starting with cold water in every part of the apparatus there is no knowing which pipe will act as the flow and which as the return, for as both openings are at a level, and as there is no influence brought into action to cause the first particles of heated water to travel up one pipe in preference to the other, there will be no knowing which pipe will act as the flow or which as the return. Further than this, the pipe that acts the part of a flow one day will, possibly, be the return on the next, and would give rise to a complaint that although hot water could be had one day, the supply was bad another day; and there is every likelihood of the servants being blamed for this, as it would be attributed to non-attention to the fire or non-cleaning of the flues.

The mere fact of one pipe standing higher than the other in the tank makes no difference whatever when starting an apparatus charged with cold water. The chief use and object of the flow pipe reaching a high position in the tank is to ensure the hottest water being drawn without having the inflowing cold water mixed with it.

Sometimes a fitter is unfortunate enough to lose his bearings, so to speak, and ends up his work by crossing the pipes, —that is, connecting the flow pipe from the boiler into the tank as a return, and the return pipe from the boiler into the tank as a flow. This can only happen in a large and complicated apparatus ; and although the water will circulate very well there is the disadvantage of having the flow pipe proceeding from the *bottom* of the tank, where the cold supply enters ; for when a tap is opened we should not get the hottest water by many degrees, it flowing as indicated by the arrows at Fig. 349. This is usually easy of remedy by transferring the stand-pipe in the tank from one pipe to another. This could only happen with the tank system, and it will be noticed that some of the faults under discussion are distinctly peculiar to this system, while others apply to the cylinder principle.

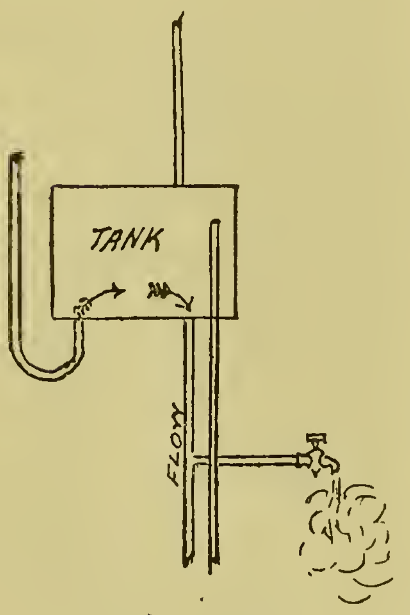

Fig. 349.

It frequently happens that, for the sake of economy, the cold supply to a cylinder is branched from an existing house service, instead of bringing down a distinct cold supply service for the purpose. This is frequently a saving of expense, but it has two drawbacks, one of them of a rather objectionable nature. The first is, that supposing we open a cold tap and a hot tap at one and the same time, as we often do at a bath or lavatory, both taps will run at an annoyingly low speed (unless a high pressure exists) as both services are fed by one supply-pipe from the cistern. With an apparatus that has a distinct cold supply, as it should have, the water will issue from both taps with an equal force, as in this case each outlet has its own distinct supply from the house cistern. This objection would not be felt, of course, if the cold and hot taps were never opened together, or if the one cold house service was of unusually large size.

The other and more objectionable feature with the one service pipe supplying the cylinder as well as the cold taps is, that if any of these latter are near the cylinder, warm water will be drawn, unless a stop-back valve is provided.

We have already explained that a very long draw-off service may be looked upon as a fault by reason of the waste of water it entails, but an instance once came to notice in which this practice caused sufficient trouble to amount to a complete failure. In this case an apparatus existed upon the tank system. with the reservoir at the top of the building as usual, and an attempt to gain the safety of the cylinder system was made by disconnecting all the draw-off services from the flow pipe and substituting a single draw-off service taken from the top of the tank and carried down the house to the different places where hot water was required. This was as Fig. 350, and the draw-off service from above the tank was about 120 feet long in all. The house being a high one, the waste occasioned neutralised the efforts of the boiler.

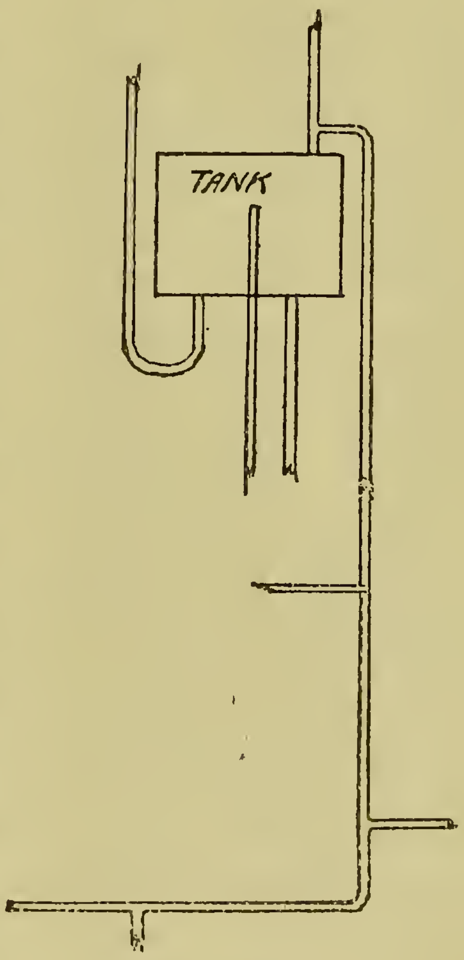

Fig. 350.

On new buildings a method is largely practised of rnnning pipes on the walls before they are plastered, the plaster afterwards being laid over them. This has certainly two good features, one being that the pipes present no unsightly appearance, and the plaster and brickwork prevent to a great extent loss of heat by radiation; but immediately the pipes require exposing for any purpose whatever a great expense becomes necessary, as it must impair the decorations, which may be costly. While the apparatus is working satisfactorily, it matters not whether the pipes are in view or hidden, but there are so many purposes for which the pipes require inspecting that trouble of a more or less serious character must arise at some time with pipes that lie beneath or in the plaster.

Closely allied to this is the trouble occasioned by omitting to put "connectors" (union pieces) into the service pipes at convenient points, so that when a pipe requires disconnecting at any particular place it may be necessary to take the pipes down for some distance, or else cut the pipe. This is a frequent source of trouble, and it often retaliates on the workman himself, as should he leave a leak to pick up (i.e. rust up), and the leakage refuses to remedy itself in this manner, then the workman has to return to disconnect and reconnect his pipes. This unworkmanlike practice of leaving leaks to remedy themselves is only too prevalent, for workmen are apt to leave leaks of too serious a nature with the hopes of their stopping of their own accord, and this induces a client to think that bad workmanship may have been introduced into the whole undertaking. A leak that only permits of one drop of water falling, say every two minutes, will, probably, remedy itself (in plain iron pipe) very soon by the mere oxidation of the metal, and the joint will be as good after this has taken place as any perfectly made one; but it is much better to remedy all leaks in a workmanlike way, as otherwise it is apt to lead to carelessness in this particular direction.

It is possible for great trouble and annoyance to arise from a very trifling cause. As an instance, we may mention a piece of loose material in the pipes. This may arise from the workman omitting to look through his pipes the last thing before using them, or it is usual for workmen, when leaving an unfinished job at night, to stop up the open ends of their pipes with a plug of hemp or other such material, which, if not carefully removed, may leave sufficient in the pipe to give the greatest trouble imaginable.

There is no fault so difficult to locate and remedy as that which may be called a "floating obstacle," and it is a fault that may not show itself except at irregular intervals.

Sometimes a stoppage will occur by a fall of "fur," which will collect at one of the angles ; this rarely occurs if the pipes are not interfered with, but if old pipes are being altered or worked upon in any way, it is one of the most common results to expect, as the jar of the tools and the hammering so often necessary in loosening old sockets, also loosens the incrusted deposit as a matter of course. A common place for the loosened matter to collect is just by the taps, as the rapid passage of the water carries it to this point, and after working on old pipes in a hard water district one or more of the old taps have nearly always to be removed to clear the pipe.

When noises are heard in the pipes of a hot water supply apparatus they may arise from various causes, many of which are peculiar to new work and of which we have already spoken. In old work they are nearly always attributable to furred pipes, which, when sufficiently obstructed, prevent a free escape of steam. The steam, consequently, has to attain sufficient strength to force its way out with more or less violence according to the resistance it experiences.

When the pipes are clear the rapid circulation of the water carries the steam with it to the point where it can escape easily, i.e. to the expansion pipe, but when the pipes are partially closed the circulation is retarded, and the steam requires to make its exit faster than the water can convey it.

This trouble is always conspicuous by its gradual growth, but when professional assistance is called in, it is, of course, usually at its height, as the occupiers of the building nearly always allow it to go on until the noises are positively alarming ; then it is necessary to take down the furred portion of the pipes and replace them with new. In almost every instance the pipes nearest the boiler will be found in the worst condition.

ACCIDENTS AND SOURCES OF DANGER.

An apparatus of the kind under discussion may be said to be perfectly safe in a general way, but like everything else it is subject to accidental circumstances, which in this instance are often sources of real danger. The element of danger is steam, but this is quite harmless if it is not confined, and has free exit and escape.

The expansion pipe is provided expressly to ensure safety, but if it becomes stopped by any means, its safety is instantly disposed of. The stoppage of the expansion pipe only, however, will not bring about an explosion, as before this can occur the pressure exerted will relieve itself by way of the cold supply service, supposing this pipe to be clear, and, in fact, if there is any possible way for the steam to escape by the exertion of pressure, it will go this way before there is any likelihood of the boiler bursting. It must be remembered that the boiler and pipes are of a strength that requires a very great power to bring about their rupture. It is on this account that such accidents are so usually fatal to life, for when an explosion does occur, the force, which is of a rending nature, is most destructive.

We may sum up the causes of accidents, by explosion at the boiler, as follows:—

1. *Frost.*—This is the general cause of such accidents, and it is really wonderful that the number is so very small from this cause. In the first place, some portion of the cold supply service to the cylinder or tank is generally in the coldest place imaginable, such as the roof, or a room just under the roof, and it follows, as a matter of course, that the expansion pipe is terminated in a similar position. Thus we have the only two open pipes of the apparatus, with their extremities in a position most favourable for their being stopped by frost. It may be taken for granted that in a simple form of apparatus, the contents of the reservoir will be brought down to a low temperature in four or five hours after the fire is extin-

guished at night, particularly in severe weather, and this leaves two or three hours (the coldest of the twenty-four) for the pipes to become frozen if it is possible for them to become so, and it must be remarked again that accidents of greater frequency from this cause ought almost to be expected.

There is not the least doubt that many and many a kitchen fire has been lighted in happy ignorance when it has been almost suicidal to do so; but there are, fortunately, many small things unknowingly done by servants and others that tend to obviate danger. For instance, there is no danger until the water exceeds a temperature of 212°, and this can only happen if the boiler is a rapid heating one, *and no water is drawn off.* If we draw water we relieve the pressure, and, what is more, reduce the temperature probably, and the opening of the tap will most likely give indication that something is wrong. Then another source of safety is present in the fact that there is every possibility of the ice in the expansion pipe melting (by the warmed water in the apparatus) before a high temperature is reached.

The conclusion we must arrive at in this matter is, that all pipes in connection with a hot water supply apparatus that are situated in cold positions, particularly in roofs, should be well covered with some poor conductor of heat, such as hair felt or any woollen material or similar substance that will prevent loss of heat by radiation.

Next in priority to frost as a source of danger is the practice of putting stop-cocks in the main (primary) flow and return pipes; this practice has already been referred to fully, and needs no further notice here, except to say that it should be condemned to the utmost of every one's power.

Another possible cause of explosion is a shortness of, or exhausting, the water supply unknowingly; we say unknowingly, as should the failure in supply be noticed, every one has sufficient sense to take some steps to avoid possible accidents. This cannot very well happen with the cylinder system of apparatus, and it cannot occur anyhow without the shortness of water becoming quickly apparent at the taps, but it was only quite recently that a serious accident from this cause was only escaped by the fortunate existence of a safety valve. It appeared that the water had been drawn nearly all away overnight, and the fire had been lighted for some hours in the morning without any one noticing the want of water, so that what little remained was evaporated. When the daily supply of water came in, some portion of it did its best to flow into the red-hot boiler, with results that need no describing. The force exerted in this instance was so great that the safety valve did not merely open but had the upper portion twisted up like a piece of crumpled paper.

The last source of danger there is to explain is "furred" pipes. This question has been practically exhausted in the previous papers, but it might be repeated that an accident from this cause, though possible, is highly improbable, as before any real danger need be feared the noises and violent shakings and vibrations must warn every one to give the matter attention promptly.

SAFETY VALVES, ETC.

There are at present but four kinds of safety valves made for range boilers, viz. spring, dead-weight, lever and diaphragm.

The spring valve shown in section at Fig. 351, is largely used, owing chiefly to its occupying but little room. It consists of an outer case A, a screw cap B, pin C, seating D and a spiral spring.

The seating is held in place by the spiral spring, which presses upon it at one end, and at the other end against the screw tap. This is where the utility of the screw portion of the cap manifests itself, as by unscrewing the cap the pressure exerted by the spring is slackened, and by screwing the cap down the spring exerts a greater force. The seating has the under side of it covered with a special compound of a rubber character so as to easily effect a watertight joint, and the outer casing is perforated to allow of the ultimate escape of the steam when the seating is lifted.

When fixing these valves, and the apparatus is charged, it is usual to unscrew the screw cap until the valve leaks, then screw it up again until the leakage ceases. It is then given one extra turn to keep it quite sound under ordinary conditions.

Undoubtedly, the proper place for a safety valve is in the boiler, but it is very desirable to have the valve in sight, and this precludes the idea of having it fixed directly into the boiler itself. The next best arrangement, therefore, is to have it fixed somewhere in sight, and connected directly with the boiler by a fair-sized pipe; there is no great risk of this pipe becoming stopped, not even by fur, as the water does not circulate within it, and if it is taken from the *top* surface of the boiler, there is not a great likelihood of the opening to the pipe being "furred" up, particularly if the pipe is screwed through and allowed to project down an inch inside the boiler.

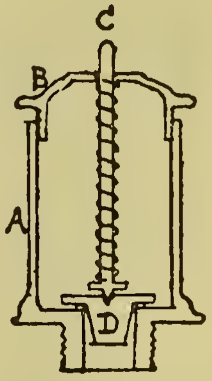

Fig. 351.

There is an idea rather prevalent that as good a place as any for the safety valve is on the cylinder (of the cylinder system). No doubt the advocates of this method have strong arguments in favour of it; but it must be borne in mind that cylinders *never* burst. It is the boiler that is the seat of danger, and where the pressure is exerted to the greatest extent; and, what is more, some of the accidents are due solely to something that occurs between the boiler and the cylinder—stopcocks, for instance.

It was said just now that cylinders never burst—neither do they; they collapse, which is a very different thing, and which a safety valve would in no way obviate. Safety valves are provided expressly to relieve a pressure that is exerted from the inside, whereas a cylinder collapses from an external cause—viz. atmospheric pressure, and an inlet valve would be the proper thing to obviate this.

The collapse of cylinders is of as great a rarity as the bursting of boilers, and it is brought about usually in this way:—Supposing a cylinder for some reason is allowed to get empty, or nearly so, and a fire is still kept in the range (a most unlikely thing), if there is any water in the boiler this will boil, and the steam will, of course, enter the cylinder. Now it is well known that there is no better means of driving air out of any confined space than by injecting steam into it, and consequently, while the steam is entering the cylinder in fair volume, very little air will remain there. While things are in this condition, if cold water is introduced the steam is condensed, and a vacuum is formed, then the pressure of the atmosphere crushes in the cylinder like cardboard. It takes but little calculation to arrive at the force exerted by the atmosphere, as we only have to find the number of square inches on the external surface of the container and multiply by 15 to have the total pressure in lbs. With a medium-sized cylinder this pressure would be about 15 tons.

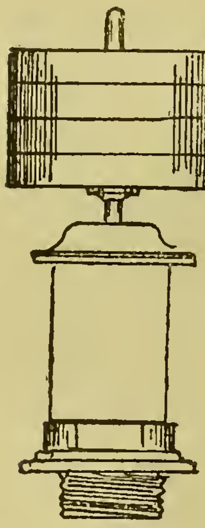

Fig. 352.

The next form of safety valve, and which is in general favour, is the "dead-weight," as Fig. 352. The body of the valve is similar in form to the one last described, but the seating is held down by weights placed and bearing upon the central pin. This is a good valve, but unfortunately takes up a good deal of room, and is not of sightly appearance, otherwise it is to be recommended on the score of reliability. This valve is still more unsuited to place directly into a range boiler, but it can be connected by means of a pipe, as described with the last. After it is fixed, sufficient weights are placed on to just prevent leakage, then an extra weight is added to keep it quite sound under ordinary conditions.

Next in rotation comes the lever valve, as Fig. 353. This is similar in internal construction to the two preceding, but the pin which bears upon the seating is held down by a weighted lever above, as shown. This is another reliable valve, but is even more cumbersome and unsightly than the dead-weight, consequently it is rarely seen affixed to range boilers, but it is a valve that must be familiar to every one, as it is much used on all kinds of steam boilers. It is a very safe valve.

The last to be described is an arrangement by which an excessive pressure bursts a thin sheet of metal, thus releasing the undue strain. Fig. 354 illustrates this valve. As the thickness of the metal diaphragm must be proportionate to the pressure on the boiler, it is necessary when ordering these to state what pressure of water exists, or, in other words, how far the cold water cistern is above the boiler; the maker then inserts a diaphragm of suitable strength or lightness. Should the valve come into operation, it can easily be put in order again by the insertion of another diaphragm.

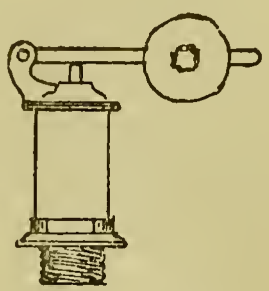

Fig. 353.

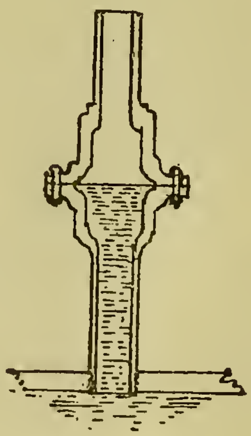

Fig. 354.

Fusible plugs are, perhaps, the most ingenious form of safety valve ever introduced, but, owing to certain drawbacks, exceedingly difficult to overcome, they are not used as freely as they would otherwise deserve to be. A fusible plug, as its name implies, is a plug or piece of material arranged to be fitted in the boiler in such a manner that, although infusible at the temperature of boiling water (212°, or thereabouts), it will immediately melt if the boiler is without water, and by its melting leave an aperture for the free escape of steam, should water afterwards flow in, and so prevent an explosion and disaster.

These plugs are pieces of soft metal, usually a disc, enclosed in a brass or gun-metal socket, this socket being screwed *inside* the boiler (to prevent injury by the poker or stoking tools). It is further made so that part of it is easily removable to replace the plug when it may require renewing.

These plugs, however, can not only be used as an element of safety when danger from shortness of water arises, but, if properly made, will answer the purposes of a safety valve when any dangerous symptoms arise with a full boiler, in the following way:—When a hot-water apparatus is working under normal conditions, with the expansion and cold supply pipes open, it may be assumed that the water does not ever reach a higher temperature than 212°, this being the boiling-point at sea-level, where the pressure of the atmosphere is 15 lbs. to the square inch. If by any means the two pipes just mentioned become tightly closed, the atmospheric pressure will not regulate the boiling and consequent temperature, and before we have an explosion it is probable the pressure exerted in the apparatus will be 100 lbs. to the square inch, this pressure permitting the water to have a temperature of 330° (approximate). This fact is utilised by making the fusible plug of an alloy (bismuth, &c.) that will melt at, say 280°; the superheated water will then effect its fusion and the approaching danger be obviated. This, however, as will be clearly understood, needs the plug to be most carefully made if it is to be relied upon.

The great objection to the fusible plug, in the South of England, is the "fur" deposit from hard waters. If the plug gets even a thin coating of this material it must suffer, as the deposit being a low conductor of heat, prevents the water from absorbing the heat from the plug as fast as it receives it from the fire. Under these circumstances it will be found that the plug may frequently fail when no danger is to be feared. With soft water there is no objection to be raised, but, notwithstanding this, fusible plugs have never gained favour, and are most commonly used as auxiliaries to ordinary valves, or to meet some special condition that may exist.

LOW PRESSURE BOILERS, ALSO FITTING HIGH PRESSURE BOILERS FOR TEMPORARY LOW PRESSURE WORK.

Boilers that have to supply water upon or below their own level only are commonly designated "low pressure" boilers in contradistinction to those that are called high pressure and have to supply water to the floors above. These boilers partake of infinite variety in shape, and they are constructed of a greater variety of materials, as not only can we have them of welded wrought iron and copper, but also in cast iron and galvanised wrought plate.

Cooking ranges that have but one oven are usually fitted with a boiler at the opposite side of the fire, this boiler being generally of cast iron, having an open top with a loose cover, and its shape and size is that which the manufacturer considers most suitable for the purpose to which it is adapted. Of all materials common cast iron is the most unreliable, as nearly every one knows, owing to its liability to crack if suddenly or unequally cooled at any time; the next best material is galvanised sheet iron, but this has a disadvantage in its being apt to laminate, that is, peel or flake, from which it soon perishes. Although this material is not likely to crack, its failure will occur almost as soon as the former material, although it will not be so sudden. A more reliable material is a good quality of soft cast iron, this material making excellent boilers; and range-makers who use this metal have but a small demand for new boilers, as only the greatest neglect will bring about a fracture. Next in lasting properties is welded wrought iron; this is given to lamination, although not to the extent of sheet iron, and, even if it were, its life would still be a long one, as they cannot very well be made of a less thickness of plate than $\frac{1}{4}$ inch. Last and highest in the scale of excellence is copper; this is necessarily costly, but it gives the best results, although if made of very thin sheet it will not do much better than some of the others. The materials that permit of general use, and which are generally satisfactory, may be said to be the good quality cast and the welded wrought irons.

When any of these boilers require renewing, a most difficult task commonly presents itself, for as a rule no means are provided for removal and replacement without dismantling the range. This sometimes occasions eight to twelve hours' work more than there need be, and the cost is, of course, proportionately increased, both in labour and material; whereas the work charged should never exceed a matter of shillings, if suitable provision is made. Every range-maker knows that new boilers are needed sometimes, and it is the most simple thing imaginable to make the provision. Instead of having the boiler screwed on to the hot-plate itself, there should be a loose panel to which the boiler can be attached, so that by removing the tap (and the union, if it is connected to a self-filling apparatus) the boiler can be lifted right out, as Fig. 355.

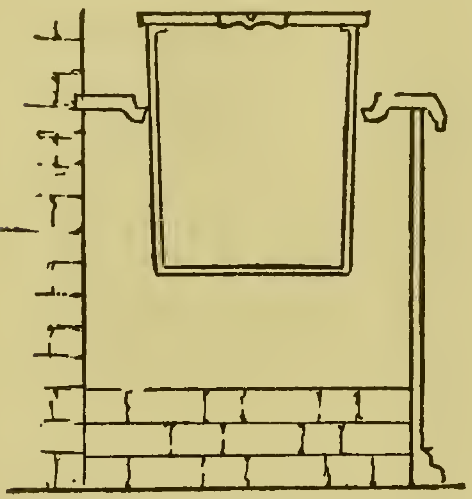

Fig. 355.

The best method of preserving the life of these boilers is to have a self-filling apparatus fitted up and attached to them, so that their being supplied with water is not dependent upon the attention of servants, for, even with the most careful, forgetfulness must sometimes occur. Even when the boiler is not forgotten it is not always kept quite full, and this leaves the part which experiences the greatest heat, viz. one side at the top, without any water behind to protect it.

In fitting up a self-filling apparatus, or when connecting an existing apparatus to a new range, there is a most serious error commonly perpetrated in not allowing the boiler to fill sufficiently. It is quite the usual practice for workmen to regulate the ball valve so that the boiler fills up within about 3 to 4 inches of the top, and this leaves the upper portion of the boiler, where the flame and heat impinge with the greatest intensity, totally unprotected. The result is that a new boiler is needed much too soon. The average workman's argument in favour of this is that "room must be left for boiling," and further, that the steam which rises from the water when it boils will serve to protect the metal the same as water. Both these arguments are quite wrong, for in the first place the difference in bulk between very cold and very hot water is only about one in sixteen, so that ½ inch is sufficient room for expansion; but to allow for ebullition as well it is best to regulate the ball valve so that the water fills up to from 1 inch to 1¼ inch of the top (when cold); this will be ample, as the water in these boilers never boils very furiously. Steam will not protect the iron, as steam, at a high temperature, is a gas without appreciable moisture.

Fig. 356 shows (in sectional elevation) a boiler fitted with a self-filling apparatus in an ordinary approved manner, and the flame passing from the fire is also shown impinging directly upon the upper part of the boiler side, as just explained, and where it is so necessary that there should be water.

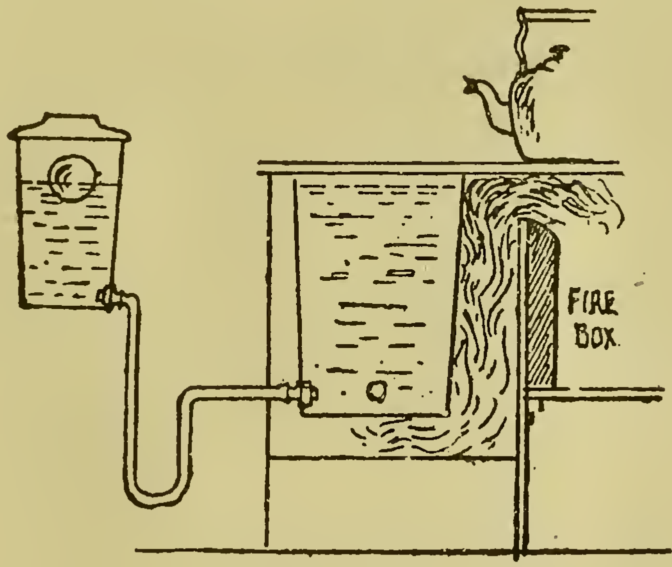

Fig. 356.

One of the most common complaints a range-maker has is of peculiar character, although an explanation will make it quite clear to any one; yet strange to say, only a small minority of our range-fitters know the simple means of remedying the trouble. The complaint in question is that the "boiler will not heat," meaning, of course, that the water in the boiler does not get hot as it should do. This complaint may be correctly stated in some instances, but as it occurs with the greatest frequency with quite new ranges, it is obvious that there is some special cause for it.

A more accurate description of the fault will be found in the majority of cases to be "that there is hot water in the boiler, but it will not flow out at the tap," and it is sometimes described in this way by the person who complains.

It will be noticed in the preceding illustration that the cold supply service is connected into the side of the boiler near the bottom, and this is strictly correct, but it will be noticed that the tap is also at the bottom of the boiler, generally within a very short distance of where the cold water enters. The action which takes place when a tap is opened is that the contents of the boiler nearest the bottom commence to flow out, and at the same instant cold water commences to flow in; now, as the cold water is heavier than the hot that may be in the boiler, it will be found that a steady flow will set in from the cold supply pipe to the tap across the bottom, hardly disturbing the heated water above. Unless remedied in the way about to be described there will be no means of getting the hot water out unless we stop the inflow of cold each time the tap is opened, or else ladle the water out at the top of the boiler.

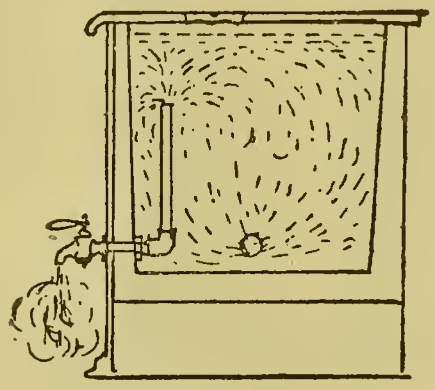

Fig. 357.

There is, fortunately, a very simple means of remedying this, as all we have to bear in mind is (as already explained on two or three occasions), that the hot water, whether there be much or little, will be found at the top of the container. Therefore with all boilers that are self-filling, the tap should be inserted within 3 or 4 inches of the top, when the range is first made; or, with ranges already made, the difficulty can be overcome by attaching an elbow and short piece of pipe to the end of the tap, standing up inside the boiler, as shown at Fig. 357. The elbow and pipe simply require to be screwed on tightly; these joints need not be perfectly water-tight, and it is the easiest remedy imaginable, except with $\frac{5}{8}$-inch cocks, as we cannot get iron elbows and pipe of this size. A $\frac{5}{8}$-inch tap needs an elbow specially made for the purpose, or a $\frac{3}{4}$-inch one can be used by soldering it on to the back nut of the cock as Fig. 358, or a piece of lead pipe, if properly secured, will answer.

The stand-pipe should terminate at top, about 4 inches below the water-level, as we must allow for the water issuing from the tap in greater quantity than it comes from the ball valve.

When a range has two ovens and has a low pressure boiler, this is most usually placed at the back of the fire, occupying the same position as a high pressure boiler would. This boiler must of necessity be boot-shaped, as a tolerably large space has to be allowed for ebullition, as the water boils so violently. If a good space is not left, then the annoyance of boiling water being ejected from the steam pipe is experienced.

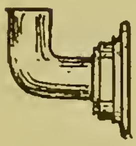

Fig. 358.

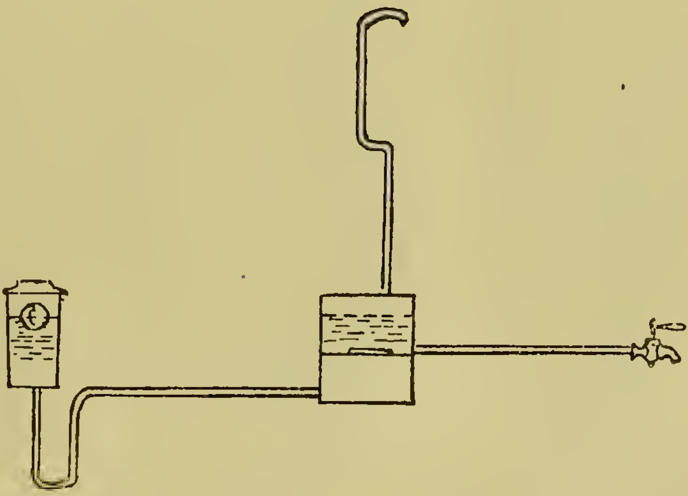

Fig. 359.

Fig. 359 shows the usual method of connecting up a low pressure boot boiler. The cold supply is carried in near the bottom as usual, and the draw-off service is taken from about 4 or 5 inches below the water-line, so as to avoid drawing cold water until the hot is exhausted, as just explained.

The ball valve should be regulated so that the boiler fills within about 4 inches of the top, so as to leave ample room for any violent motion of the water. There is no objection to this large space in this instance, as only the lower part of the boiler comes in contact with the fire. The real object of the large space is to permit a free escape of the steam *above* the water, as should any particles of water be thrown by their motion into the mouth of the escape pipe, the steam will instantly eject them into the chimney, sometimes a pint of water at once. All pipes that are run behind ranges should be iron—never lead, as there are numerous enemies to this latter pipe, and should a leakage show itself the range has to be removed before a repair can be effected. This also applies to ranges with side boilers, when it becomes necessary to carry a pipe round the back or beneath the range.

It will be noticed in the drawing that there is a "set" or crank in the steam escape or expansion pipe. This answers a very useful purpose in preventing any small quantity of water from being ejected. When the water (unless in quantity) is propelled up the steam pipe, this obstruction will prevent its free passage and escape into the chimney under ordinary circumstances. These boilers should be of welded wrought iron.

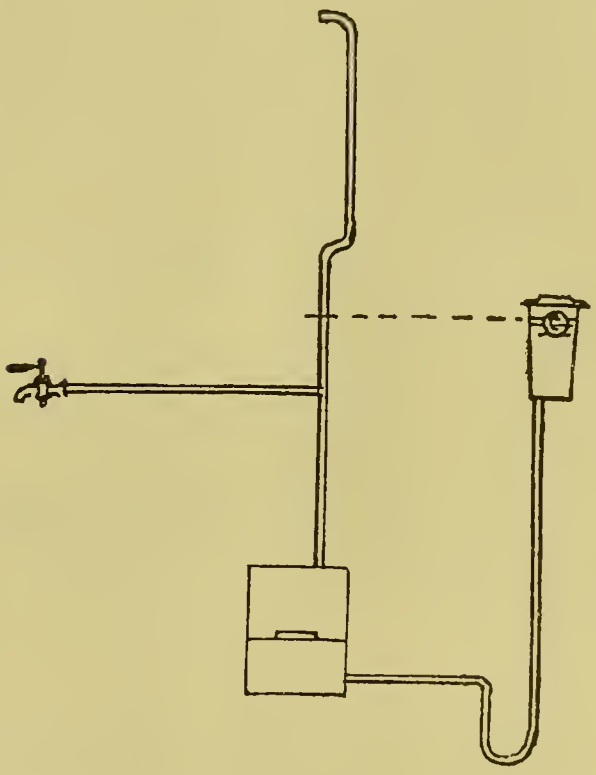

Fig. 360.

Sometimes a low pressure boiler is used for supplying hot water above its own level by regulating the ball valve to a height that will allow of the water rising up within the expansion pipe, as Fig. 360. This will answer, certainly, but if the boiler is a rapid heating one, a good deal of annoyance will be experienced by the steam forcing water out of the pipe, even if this pipe is carried to an unusual height. Or should the steam experience any difficulty in escaping, it will probably make its way through the cold supply cistern, causing this to overflow. This arrangement cannot be recommended. It is better to have the water drawn from the level of the boiler, or else have a small tank and circulating pipes fitted up.

The ball valve, which is an essential feature in the self-filling apparatus of a low pressure boiler, is frequently a source of complaint. Every practical man knows that a ball valve anything near perfection has not yet been made; but perhaps of the different varieties those that are constructed upon an equilibrium principle give the best results. Ball *cocks* are now losing favour, as they act so slowly in filling a boiler. While the level of the water is low the cock admits an abundant supply, but as the level rises the supply decreases gradually, so that when the water is within one inch of its accustomed level the water is only dribbling in, and this slowness in filling gives every opportunity for the fire to injure the boiler plate, besides being objectionable in other ways.

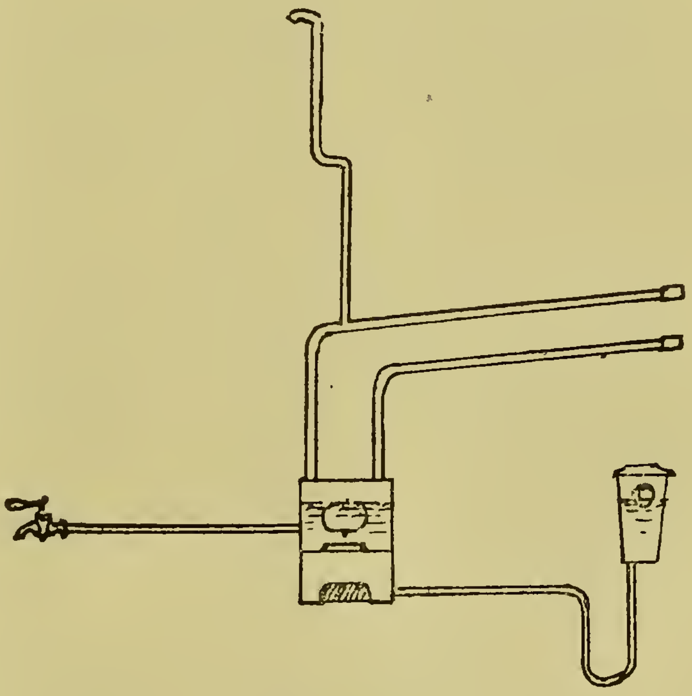
Fig. 361.

The fitting up of a high pressure boiler before the circulating apparatus is erected, so that the boiler may be used for low pressure purposes temporarily, sometimes for a few months, is of common occurrence, and can usually be arranged without difficulty or great expense. This can be done in two or three ways, but the least expensive method costs the most to reconvert when the hot water circulation is ready, and *vice versâ*.

The least expensive method is to fit in the high pressure boiler and construct the flue to it at the back of the range, and then to carry a flow and return service from the boiler just through the chimney jamb (as Fig. 361). These two services are capped off until required for circulation. From the flow pipe is carried a steam escape pipe as shown, but the boiler is fed and drawn from in the same manner as a low pressure boiler. The flue under the boiler requires to be stopped while it is used for low pressure purposes; this is best done by a piece of fire-brick cut to shape, as it is easily removable, leaving the flue clear when needed.

When the conversion is made, the flue is cleared as just explained, the flow and return services are uncapped and connected, the steam escape and cold supply pipes are both stopped off, and the draw-off tap can be left as an emptying service if the tap has a loose key. It is then ready for use, provided the circulating apparatus is complete.

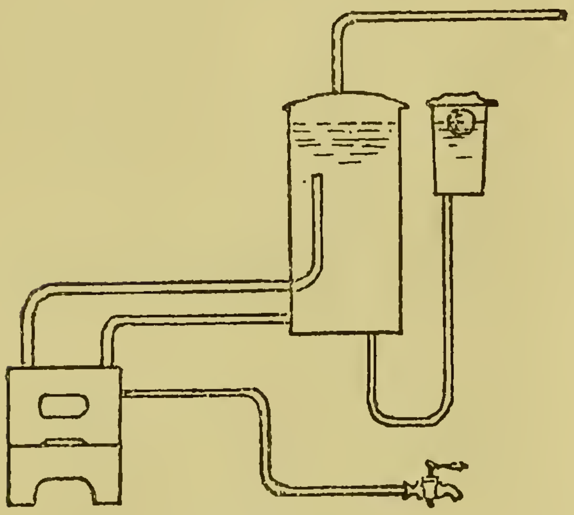

Fig. 362.

Another method is to complete the apparatus from boiler to cylinder, but supplying the cylinder temporarily with a supply cistern, as Fig. 362. This is without doubt much the best arrangement, if the conversion is to be made afterwards, for when it is done the future work is reduced to a minimum; in fact, it is hardly necessary to put the fire out, all that is needed being to complete the apparatus *above* the cylinder, the draw-off tap below answering for the emptying service. By this arrangement very little expense is incurred beyond that which is necessary to the complete apparatus.

In conclusion, let it be the ambition of every one to do this work really well. There is no branch of mechanics which will permit of careless labour so little as this, and workmen have an opportunity of displaying ability and discernment to a far greater extent than in many other trades.

CHAPTER XXIII.

COMBUSTION: ITS APPLICATION TO WARMING PURPOSES BY GRATES, ETC.

Stoves and grates—Value of radiant heat—Smoke—Slow combustion, advantages and disadvantages—Utility of the "blower" to grates—Dr. Arnott's principle and its unique value—Fire-brick and poor heat-conducting materials—Grate backs and other improvements—Process of combustion—Carbonic acid and oxide—Bituminous fuels—Products of perfect and imperfect combustion—Carbon and hydrocarbon—Soot.

THE prevailing idea as regards the combustion of coal fuel, is that all introductions and improvements in grates, stoves and fuel-burning appliances, should tend to increase results with a given quantity of fuel, or, in other words, be more economical than preceding patterns in attaining the desired effect. This argument is very good in its application to mechanical requirements, and decidedly so with hot water works, but it does not apply generally, that is, to every purpose. If it did the open grate, even in its most approved form, would not exist at all.

The process of combustion is seldom effected in a perfect manner with a bituminous fuel (ordinary coal) owing to the existence of the volatile matters in its composition which are largely released before the temperature is sufficiently high to ignite them. The combustion, however, is more perfect in any form of furnace or close stove than in an open grate; yet supposing the combustion was carried on equally in both appliances, the results would be far less in the latter than in the former owing to several causes. The chief of these is that only radiant heat is obtained from the glowing coal in an open grate, for the air is not heated; and all flame is next to useless for radiating purposes, although it is of great value for contact work. This latter effect is readily ascertained from an ordinary gas flame.

With any form of boiler or stove it is possible (by its proper construction) to utilise nearly the whole of the heat evolved from the fire, or at least all that is capable of useful effect, and the gases that ultimately pass into the chimney need only be of a comparatively low temperature. As a rule this is the result aimed at by all boiler-makers and most stove-makers.

It might be roughly computed that an efficient hot water apparatus, in which no waste of heat occurred from the mains, would heat, say, ten rooms in a residence with the fuel that would be consumed in four or five rooms with ordinary open grates. If the grates be of an approved modern type slow combustion, with the best form of fire-box for effectiveness, a little lower estimate may be taken, but still the hot water apparatus would be decidedly the most economical. Hot water engineers urge other features in favour of their speciality as against open grates, such as less attention, &c., but their other chief point is equable temperature, heat projected towards the body from all sides, and not from one point only as with a grate. (This objection with the grate can only apply if the whole of the room has not attained its proper degree of warmth.)

This is always considered a very strong case for the hot water engineer, but at present it is more than counterbalanced (in the public mind) by the advantages possessed by the open grate and which have not yet been referred to. Chief and foremost of these is the fact that wholly radiant heat is considered more healthful and congenial to human life owing to the peculiar effect it has in passing through the air without raising its temperature,* and in this it acts most naturally, for the sun's rays are received in the same way. It will always be found that the most agreeable sense of warmth is that which fully heats (and sometimes a little overheats) the body, but which leaves a moderately cool air to breathe, and the open grate largely fulfils this, particularly as it in itself constitutes an effective source of ventilation. But the average grate, although representing a desirable means of heat-distribution, effects its purpose very imperfectly, so far as the combustion of fuel is concerned and the results obtained for the fuel consumed.

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* In hot water works, particularly when the pipes are not exposed, the heat is chiefly contributed by heating the air.

If it were that this valuable feature did not exist with open fire-places it is possible they would still survive, for a real difficulty would be experienced in discarding the many pleasant associations that are supposed to be connected with the very appearance of the fire ; its cheerfulness would be missed for a long time. It is even a very common practice to have fires in living rooms that are heated by other means, but which means are checked sufficiently to prevent overheating when the fire in the room is alight.

The material which goes to make flame, smoke, and soot deposit is, as every one knows, fuel in a new but wasted form. On this account it is rather surprising that coke is not more freely used in open grates as there are several features in its favour, the abatement of smoke not being the least. A coke fire carries quite as good an appearance as one of coal, for the latter fuel does not please the eye less when it is in a glowing coked condition without flame—in fact, it is generally at this time that the fire looks its best, and it is decidedly at this time that the greatest heat is radiated. Coke fuel, if used in a proper form of grate, quickly assumes this desired state without the preliminary stages that coal has to go through.

The difficulty that would be experienced in using coke for the ordinary grates or the modern "slow combustion" variety, would be in getting the coke up to a bright heat, as this fuel is not successful if put upon a low fire with no means of causing it to draw up quickly, and the difficulty would be even increased when first lighting the fire. But the whole trouble can be so readily overcome by using a blower—a most desirable adjunct to any grate ; for at no time is it desired that a grate be a long time lighting or burning up.*

This brings to notice the particular and a really pronounced objection to the majority of our modern "slow combustion" grates which are slow always. When first lighted in the morning they do little else but pour smoke into the chimney for some time, and the same thing happens whenever the grate receives fresh fuel in fair quantity.

Speaking of "slow combustion" which is effected by decreasing the quantity of air that is allowed to pass through the fire,† calls to notice the principle introduced into Dr. Arnott's grate. It is unnecessary to describe the grate itself as it was somewhat complex, and on this account and the trouble of fixing, fell into disuse, but why the peculiar and valuable feature of the grate was lost sight of cannot be understood, and it certainly shows a want of perception somewhere. The peculiar feature referred to was the ability to keep the fire (of ordinary size) alight a great number of hours without attention, the construction of the grate being such that the fuel could be surrounded as if it were in a box with only the top open. The effect of this was not to extinguish the fire, as might be supposed, but to render it stagnant or stationary; ingress of air to cause combustion was prevented, yet not sufficiently to cause the fire to go out.

This result is quite possible, and practicable from a manufacturer's point of view. There is one maker adopting the method at this moment in an eminently successful way, yet valuable and appreciated as the principle is, this maker stands alone, for the manufacture of grates moves slowly so far as practical improvements are concerned.* In Dr. Arnott's grate the fuel could be kept alight from twelve to twenty hours without attention, and in the other one just referred to, the fire will with the greatest regularity keep alight fourteen hours without attention. The result is effected in the same way in each case, viz. by keeping the passage of air from passing not only through the bottom of the fire, but also having means provided to prevent air passing through the front of the fire, the top only of the fire being exposed and the fuel receiving from the top just sufficient air to keep the fire alive. Combustion can hardly be said to go on, the fire appearing to be asleep.

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* There are several grates made with blowers more or less a success mechanically, but this attachment should be more universal, whatever fuel be used.

† This is done by making the bottom of the fire-box of solid fire-brick (iron would not do, by reason of its rapid heat-conductive properties), or else by placing a grating at bottom, and preventing air passing through it by closing tightly the front space between the bottom edge of the front bars and the hearth. This latter is the best, and generally recommended plan, as it permits of the accumulated ash being easily disposed of.

It will be seen that this is of particular advantage for very many purposes, such as for sleeping or invalids' rooms (for the fire continues to give out a moderate heat) or for any apartment that is left for three or four hours. With a grate like this there is no reason why any room should be allowed to get so bitterly cold as they commonly are in the early morning.

For the proper combustion of coal it is essential that the fire-box be bounded on both sides, and the back, by fire-brick, and not by iron ; fire-brick is well adapted for the purpose, but any material would do if it could be used in blocks or slabs and had a poor heat-conductive power equal to or lower than that of fire-brick. Nothing that conducts heat rapidly should ever be used, or the fire in contact with that part will be dead and unlike a fire, and this occurs to a great extent even if the iron is backed up with brickwork. If it were possible to utilise silicate cotton † in this way it would be eminently successful, and probably it would overcome the trouble that is constantly present with fire-bricks, which so readily become fractured, as they are not in the least of a fibrous nature.

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* In the beautifying of grates and stoves the different makers show a praiseworthy interest ; but there is a deal of this ingenuity expended upon useless and almost barbarous appliances. The dog-grate is the worst contrivance of this sort, yet, if stood in a nicely tiled opening, makes the most beautiful looking fire-place imaginable.

† The heat of an ordinary grate fire would be sufficient to fuse this material in its ordinary state.

The shape and position of the fire-bricks in a grate very greatly influence the results obtained in radiation of heat, and also, to some extent, the utilisation or lessening of the otherwise wasted flame and smoke products. It is doubtful whether the dog-grate * is more wasteful of heat (consequently fuel) than the old form of register grate which has a semicircular opening immediately over the fire-box at the back. If a good fire is established in the latter, the flame and a decidedly major portion of the heat evolved pass directly from the burning mass through this opening into the chimney. This result (with this grate) is entirely due to the opening being so close down to the fire, and to the back of the fire sloping backwards so that the products can have the freest possible escape into the chimney. The heat received into the room is practically confined to that which may be emitted from the front of the fire only. Added to this, the closeness of the chimney opening to the top of the fire causes a much higher speed of combustion than is needed.† The closer the chimney opening is down to the fire the less opportunity there is for the utilisation of gaseous products, and the radiant heat which

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* Also commonly called a "fire-basket."

† As a rule, the speed of combustion in open fire-grates is greatly influenced by the distance between the fuel and the entrance to the chimney. If we use a blower which reaches right down to the front bars, we practically bring the chimney entrance down also, so that no air can pass into the flue without passing through the fire, and this effects the highest speed of combustion. If, on the other hand, we make the space between the fuel and the chimney opening two feet, which may be considered the maximum distance, we get the slowest speed of combustion (supposing the construction of the fire-box is of approved design). As we increase or decrease the space, so it will be found that a lower or higher speed of combustion is attained ; in other words, the greater opportunity the air has to pass into the chimney without affecting the fire, the slower will be the speed of combustion. This means of reducing the rate of combustion has, however, to be resorted to with care, as unless a blower is provided, some of the smoke may come into the room when the fire is first lighted, or when it is replenished with fuel.

is required in the apartment is to a great extent expended uselessly, as the apartment does not get the benefit of it.

There is a great diversity of opinion as to the best shape of the back brick to an open fire-grate. There is an agreement as to the effect that is required, which is to prevent the heated products, and also the radiant heat, from having a straight passage into the chimney. This is effected by causing the back brick to lean forward and overhang the fire-box, so that nearly all heat and heated matters have to come in contact or be influenced by this projection. The projection has another good effect in partially choking the entrance, or what is commonly called the throat, of the chimney. There is no gain whatever in allowing such a great volume of air to pass up the chimney more than is needed to convey the smoke, as this helps to cool the chimney and reduce its efficiency.* Although an open grate is looked upon as a powerful outlet ventilator its power should be somewhat limited, otherwise the draughts at the doors and window crevices, &c., will be objectionable.

In reducing the throat of the chimney, care is needed, for although a small opening might suffice when the fire is bright and the products of combustion lessened (gases only—no smoke), this small outlet will not do if the fire is giving off smoke freely, and there is no necessity whatever for making the opening unreasonably small. The chimney throat, whatever its size (within practical limits), makes no actual difference to the speed of combustion unless, as before mentioned, there is a clear straight way from the fire thereinto, and no device exists for preventing a free escape of heat and heated products.

Figs. 363, 364, 365 and 366 show in side section several different modern grate backs, all designed with the object of benefiting by the heat evolved from the fire to the utmost possible extent; but it follows as a matter of course that as they vary so greatly in shape they must vary in results also. From experiments made and many results noted, the writer is of opinion that Fig. 366 is the most effective shape, besides being free from some various little disadvantages in wearing properties that other shapes possess.

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* If the chimney is a fairly tall one, its efficiency could not so very readily be spoiled in this way, although this is the usual cause of dog-grates smoking.

The reason for speaking in favour of Fig. 366 is that, to reap the fullest possible benefit of otherwise wasted heat and heated products, the back brick of a grate must be made to perform two offices. First, there is the absorption of heat from flame contact, to the greatest possible extent. This can only be obtained by giving the greatest possible surface for the flame to impinge and act upon, this absorbed heat then being radiated from the intensely heated fire-brick into the room.* Secondly, the projection of the brick causes the heat that is radiated from the top of the fire (which represents a valuable amount, the top being frequently the hottest surface) to be deflected into the room instead of passing into the chimney.

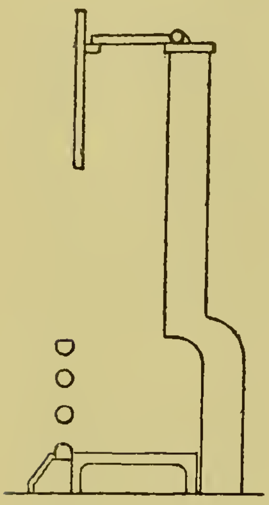
Fig. 363.

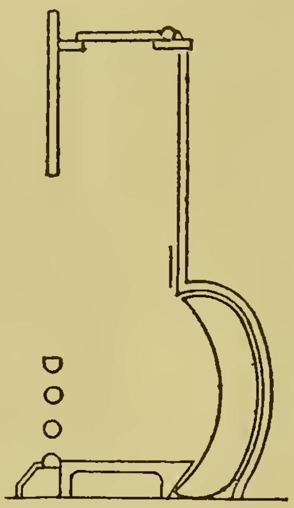
Fig. 364.

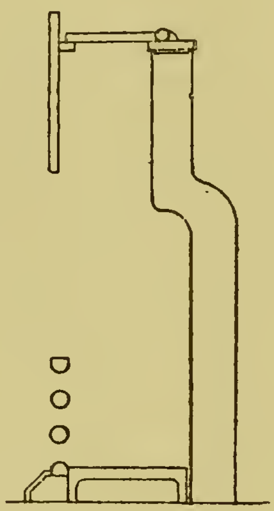
Fig. 365.

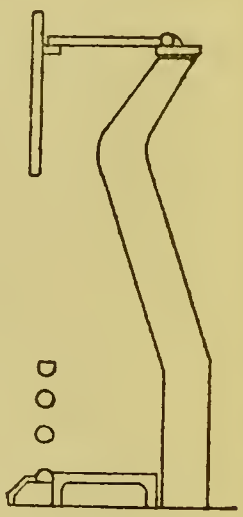
Fig. 366.

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* Radiated heat proceeds in straight lines from the heated body; thus an overhanging brick projects a really great amount of heat towards the floor, where it has a most useful effect, for the top of a room only too readily gets warm to the prejudice of the lower portion, the warmed air so quickly rising. We have also to remember that the currents of cool air which proceed towards the fire and pass up the chimney, are more inclined to seek the floor than a higher level.

It will be found from any simple experiment that a surface overhanging a bright fire will cause a very sensible and instantly noticeable increase of projected heat,* due to the radiant heat that would have been directed up the chimney, being turned from its course, or deflected, by the overhanging surface in question. This deflection takes place in practically the same way as light would be reflected if the surface were a mirror. Fig. 367 shows these two particular ways in which the overhanging brick utilises radiant heat and heated products, the unbroken lines representing radiated heat from the hot fire-brick † and the dotted lines the deflected radiant heat from the fire.

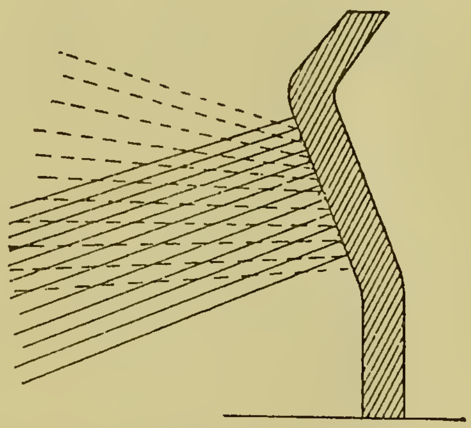
Fig. 367.

The brick should overhang the fire at least half-way, or three-fourths if possible, the exact distance cannot be stipulated, but it may come as far over as it can be got so long as a space of not less than from 2½ to 3½ inches is left between the top front edge of the brick and the iron curtain or canopy in the front of the grate, this space extending the whole width of the fire-box. The size of this space or throat would of course vary with the size of the grate, but the principal care is to see that it is not made too small to admit of the smoke being carried off when the fire is first lighted or fed heavily with coal. As Fig. 366 shows, the brick should continue to lean forward for a few inches above the lower edge of the curtain or canopy of the grate, and then it should turn back somewhat abruptly as shown.

If the mass of fuel is thin, even if it be surrounded with fire-brick, combustion does not take place at all perfectly; on this account a grate fire has to be of a required thickness, although the effect required only proceeds from the front and the top. At the same time a fire of an unusually large mass is a source of waste by the formation of carbonic oxide, as will be explained.

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* The common form of register grate, with a flap to close the opening just over the back of the fire, can be made to demonstrate this, by nearly closing the flap, so that it leans over towards the front; a piece of cinder will hold it in this position for a short time.

† These back bricks get to a very high temperature, appearing quite clean when in use, as the heat is too great for soot to be deposited.

Combustion * is effected by the chemical union of oxygen and carbon, the oxygen being furnished by the air and the carbon by the fuel, the union being effected with the utmost rapidity, but not until the combustibles have reached a tolerably high temperature. If we use coke, charcoal, or anthracite coal we may look to get practically perfect combustion, as the gases which leave the fire will be found to be almost wholly carbonic acid, nitrogen and water. There is, of course, an evolution of heat which, however, can scarcely be called a product, it is more a result, and the nitrogen is neither, as it is simply the atmospheric air which having passed through the fire has been robbed of its oxygen.

As the air (which consists of an admixture of oxygen and nitrogen) enters the fire, the oxygen readily separates itself and unites with the carbon of the fuel for which it has an affinity, and which we must suppose is in a glowing state. The union of oxygen and carbon produces a gas known as carbonic acid (or carbonic di-oxide) the proportions being two atoms of oxygen to one of carbon (CO_2). This is the effect if the layer of fuel on the fire bars be fairly thin as is recommended in feeding boiler furnaces; but if we get a large and thick mass of fuel the carbonic acid, which is formed almost immediately it enters the fuel, undergoes a change if it cannot leave the fire at once. It takes up another atom of carbon and becomes carbonic oxide (C_2O_2 or CO), which is a combustible gas and can be noticed burning with a rather beautiful blue flame on top of thick coke fires. The wasteful effect of carbonic oxide formation is due to its taking up or robbing the fire of carbon but evolving no heat when it burns

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* So far as it relates to this chapter.

and is re-converted into carbonic di-oxide in the air at the top of the fire. When oxygen combines with carbon great heat is evolved, but when carbonic acid takes up carbon and when it parts with it again no useful effect is produced and the carbon is lost. In a thick coke fire we may consider that the combustion produces carbonic acid for about three to four inches from where the air enters, and from this point the conversion into carbonic oxide is effected and continues to the top where it is consumed in union with the air it finds there, and becomes CO_2 again, as Fig. 368.

Now, combustion as perfect as that just explained cannot be effected with any bituminous fuel, as the volatile compound, bitumen, contained in it, defeats this end. Bitumen is a substance, we may say, wholly composed of hydrogen and carbon, this compound not existing in the coal in a separate form but being thoroughly incorporated in it. Coal might almost be considered as bitumen itself, but having an unusual proportion of carbon in it. The percentage of hydrocarbon in coal varies greatly, being very abundant in cannel and practically absent in anthracites, the latter being very nearly pure carbon.*

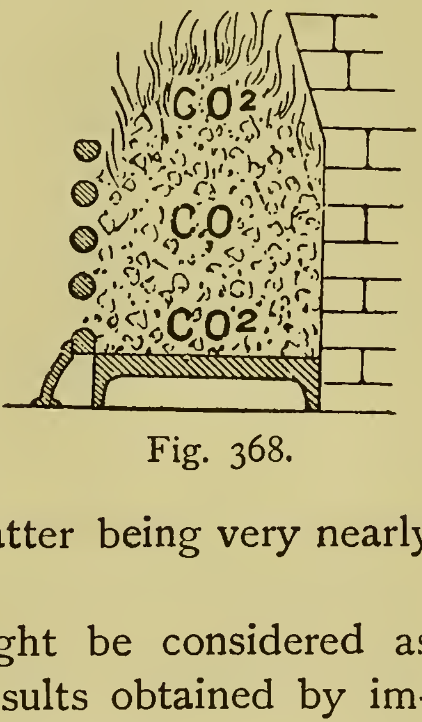

Fig. 368.

The effect of bitumen, which might be considered as solidified tar, is to bring about the results obtained by imperfect combustion, such as smoke and smoky flame, by reason of the hydrogen being so readily released, or distilled off by heat before the temperature is sufficient to ignite it. If this substance remained in combination with the coal until a fairly high temperature was reached, it would be ignited immediately it released itself and combustion would be perfect or nearly so. Many may have noticed this result in some hard coals, which flame, but produce a less percentage of soot, but this advantage is always accompanied by a difficulty in getting the fire to light.*

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* All coal fuels are more or less charged with impurities, sulphur in particular, and earthy salts, which go to make ash.

The production of soot is reduced to an agreeable extent by using a blower to a grate, when the fire is first lighted or heavily charged with fuel, as by this means we much more rapidly induce a high speed of combustion and an intense heat. A greater volume of oxygen is thus caused to come within the area of combustion, and in a few minutes a fire can be got bright and fairly free from smoke, the blower can then be removed. In the modern form of slow-combustion grate unprovided with means of hastening the lighting of the fuel the quantity of smoke poured into the chimney from a newly lighted fire is stupendous and, strange to say, the objection is quite recognised. No good comes of the waste, and only loss of time, loss of heat and fouled chimneys result. Slow combustion has excellent qualities when a fire is bright, but at other times it is not only objectionable, but really amounts to an evil.†

When hydrogen exists in a fuel we obtain another product of combustion, that is, one more than we get by burning coke. Of the two substances, hydrogen and carbon, which constitute bitumen, the latter (if consumed) goes to form carbonic acid or oxide, the same as with the carbon of coke, while the former, released from the carbon, undergoes combustion and combination with oxygen to form water, in the proportion of two atoms of hydrogen to one of oxygen (H_2O). This water leaves the fire in the form of a gas, but quickly assumes the recognised appearance of water as it becomes cooled. The presence of water in the products of combustion can be ascertained in a very few moments by holding any cold surface just over the burning materials when the water will be condensed upon it. This is most effectually tested by holding a slab of iron or an earthenware tile or plate for a few seconds over a gas flame, when moisture will be found on the surface where the products of combustion have impinged upon it. The colder the surface the more quickly the moisture will appear.

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* As a rule, a difficulty in lighting the coal is due to its less percentage of bitumen, but not always.

† If a group of houses be noticed any winter morning, all the chimneys which are in use will be seen to be smoking heavily for about one hour the first thing, after which time the smoke is greatly reduced, as the fires have become bright, and the material surrounding the fires becomes hot, then at intervals the smoking starts again as the fires are fed; but all this smoke could be reduced to a comparatively trifling amount by the use of a blower. Chimneys should be kept clean when a blower is used, but at the same time the blower aids in this by reducing the smoke (soot).

Hydrogen aids very materially in igniting the carbon, and by its presence coal can be lighted readily from a few pieces of wood without a keen draught or superabundant supply of oxygen as we get when a blower is used. Except for this the presence of hydrogen is somewhat objectionable, not only on account of its volatile propensities, but from the fact that it produces water which carries such a deal of heat with it. The same effect is produced if we use damp fuel ; we reduce the resulting heat greatly as water has great capacity for heat and carries it off from the fire abundantly. The amount of heat absorbed by one pound of water to raise its temperature one degree would have the same effect upon about thirty pounds of mercury.

CHAPTER XXIV.

CHIMNEYS.

Draught in chimneys, cause and effect—Causes of sluggish draught—Stoves *v.* grates—Sizes and areas of chimneys—Suggested sizes for horticultural works—Residence chimneys—A common, but little known cause of trouble—Pipe chimneys—Descending chimneys—"Pilot" stoves.

BEFORE speaking of the relative sizes of chimneys it is necessary to deal with the draught which entirely controls the successful purpose for which the chimney is erected. There is much similarity between the cause which promotes this upward current of air, and the cause of circulation in a hot water apparatus, for both result from a difference in weight of two columns of fluid—the column which has the greater weight compelling that which is of less specific gravity to rise and escape from its influence and force.

In a perfectly new and cold chimney no draught whatever exists, but after the chimney has existed a little time a draught of slight strength will commonly manifest itself, due to the still air in the new building getting just a trifle higher temperature than the air outside,* and a difference in temperature of a fraction of a degree is sufficient to induce a fairly quick current. By this reason it is a common experience to find a noticeable draught in the chimneys of a building where no fires have as yet been lighted. When a fire is lighted at the base of a new chimney it is not unusual for some smoke to come out into the room, as the weak draught alluded to is insufficient to take away any volume of gases and smoke, but this smoking does not usually last more than a few minutes and a rapid and efficient draught then sets in permanently.

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* This cannot be said to apply during hot weather, when the conditions may be reversed.

If a chimney, which has had some use, is left unused for a time, it is really surprising how long a period a good and capable draught will keep up within it. This is not, however, due to the difference in temperature within and outside the building, but is brought about by the heated brickwork of the chimney itself. When the heated air and products are passing up a chimney it follows that the surrounding brickwork absorbs heat and becomes of a good warmth, and if the fire is extinguished the brickwork will transfer sufficient heat to the air in contact with it to keep up the draught with very efficient strength for many days. A draught of sufficient speed to prevent smoke coming into the room when a fire is lighted will exist for quite a long period, this draught being almost wholly due to the heat given out by the brickwork, as this material parts with its heat very slowly.

The efficiency of a chimney draught is increased by adding to the height of the chimney, also by raising the temperature of all air and gases entering it. If the air of a room and the gases within the chimney differ by, say, 50°, there will be a difference in specific gravity of about one-tenth. Thus, with a chimney 20 feet high, under these conditions, we should have a force exerting itself to urge the contents of the chimney upwards, equal to the weight of a column of air 2 feet high, and this, it will be found, is sufficient to cause a draught that leaves nothing to be desired. With a chimney of even half this height we shall still have efficient results (surroundings being favourable), but as the majority of chimneys exceed 20 feet, there is never any trouble experienced unless some influence is brought into play that counteracts the results here mentioned, or retards and prevents these results being ever attained. The efficiency of the average chimney is so actual, that the opposing influence has to be fairly strong to cause any real trouble ; there has to be something radically wrong for a chimney to be unsuccessful in carrying away the products of combustion.

One rather prolific source of trouble in this respect is the admission of cold air into the chimney, that is, air which has not passed through the fire nor even been near enough to it to be warmed. This can happen in one or two ways, a hole in the chimney being one, as it not only admits air that has a seriously cooling influence, but as we may suppose the hole would be at some point above the fire (not being likely to be below it) we shall find the fire will suffer from a want of draught. The chimney will be inclined to draw its air through this hole to the prejudice of that opening which is provided at the base for the smoke to be taken through from the fire. It is, however, rather unnecessary to speak further of this as every one should know that no holes, passages, or even crevices should exist in a chimney, only the two recognised apertures being permissible, one at the fire-place at bottom and the outlet at top.

The common way by which cold air enters the chimney to such an extent as to prejudice or imperil its efficiency is by having the opening over and around the fire larger and out of proportion with the fire itself, as we get in a dog-grate, which is a fire-basket set into an opening about five times larger than it ought to be. Unless the chimney is a very high and effective one the products of combustion will not be carried away at all satisfactorily.

The best way of illustrating this is by describing a very old offender in this respect, the old pattern open kitchen range. These ranges when placed in an opening of ordinary height almost invariably smoke, and they then require partially closing across the top by a blower to effect their cure. The good effect is brought about by the blower causing the air which enters the chimney to come under the influence of the fire and be warmed.* At no time do we get a good working draught with these ranges owing entirely to the great air space which exists just over the level of the fire. The smoke and gases always seem to be acted upon by some depressing influence, and seek every opportunity to ooze out into the kitchen, even with a good chimney, for a kitchen chimney is usually one of the highest, from 40 to 60 feet, if the residence be a fairly large one.*

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* A blower extending a little way down the opening would oftentimes cure a dog-grate of smoking.

If we displace this open range and insert one of a modern closed character, what a different result! There is no need to make the slightest alteration to the chimney itself, yet we get a marvellous change in the nature of the draught. It no longer seems weary in its efforts to carry the smoke or part of it up the chimney, but open all the dampers and the draught will cause a roaring noise in its mad race through the flues, drawing great tongues of flame around the ovens. The change is all the more wonderful when we remember that with the open range we merely wanted the smoke to go straight up into the chimney as would be natural for it to do, but with the closed range we require the draught and products to first travel horizontally, then downwards, and then horizontally again, before ascending, and it does it more than willingly. The great difference in these two examples is due to there being an unreasonably free flow of cold air into the chimney in one case, and a total exclusion of cold air in the other; of course any intermediate course can be adopted as desired.

The trouble with the dog-grate, open range, or any form of fire-place in which cold air has too free an ingress into the chimney, is not always experienced when once the fire has got hot and the chimney gained as much as possible in temperature (which, however, it is seriously prevented from doing by the never ceasing inflow of cold air). At first lighting, such stoves are of the greatest annoyance, but this could be minimised or perhaps entirely obviated if a deep blower were used at such times. By excluding cold air for a time there is an opportunity for the chimney to get warmed, and further, the fire gets into a hot, perhaps a glowing, condition and the trouble is probably over. A blower does excellent service with chimneys in which, from some cause or other, the draught is sluggish, this sluggishness always being particularly objectionable when first lighting the fire.

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* In many modern-built houses the kitchen is placed in a "back addition," a piece attached to the main building. These back additions are not always so high as the main building, in which case the chimney is not only shorter than usual, but its top comes below its surroundings, and trouble must ensue. Why houses are built in this way—and there are a vast number—is hard to conceive. Every chimney of a building should terminate well above the building; but this will be referred to again.

SIZE OF CHIMNEYS.

In horticultural works there is no fixed rule as to the size a chimney should be, except that sort of rule which is generally called judgment. There would be difficulty in compiling a table for the purpose, as the area of a chimney is regulated not only by the size of the boiler, but also by its own height. A high chimney inducing a keen draught need not be made of so large an area as a low one, as is most commonly the case.

Firstly, as to the height, it is only necessary that the minimum height be given, as there need be no fear of ill results in increasing the height if a stronger draught is wanted. If circumstances permit, it will be found best to exceed these heights, as they represent the actual minimum, which must only be expected to give just passable results. The object in showing the least height for these chimneys is that in horticultural works one of even moderate height can scarcely be tolerated. Unless the works be for a professional grower, the chimney is considered a most unsightly object indeed. Of course, where the houses and gardens are worked for profit only, almost everything is sacrificed for profitable results—an almost opposite state of things to what exists in a gentleman's private grounds.

It is usually laid down that with horizontal boilers the chimney should always be of a height equal to the aggregate length of the flues which pass up and down the boilers, so that a saddle boiler 4 feet long, having the flues once up and down it, should have a chimney 8 feet in height. This will suffice as a minimum. If the flue traversed the length of the boiler three times the chimney should be 12 feet high. Under exceptional circumstances these heights could be reduced a trifle, although it is unusual for 8 to 10 feet to be inadmissible. If the boiler be a large one, say 8 feet long, flued once up and down, it would be possible to work it with moderate efficiency with 12 or 14 feet of brick chimney, but this should only be attempted if the circumstances are really exceptional.

With a vertical boiler which has flues carried vertically up and down it, a little larger allowance of chimney must be made, as the draught experiences more resistance or work in having to travel in a directly downward direction than it does in passing along a horizontal way ; in such a case twenty-five per cent. greater height of chimney should be given as the minimum.*

In internal area it is more difficult to fix upon exact sizes, as we cannot show any relationship to the area of fire-bars ; for it will be seen that the area of fire-bars varies with the character of the boiler ; and again, a boiler used with coal fuel should have a larger sized chimney than one burning coke, as the fouling by soot reduces the actual area. For general purposes the following sizes will be found efficient :—

	Area of Chimney, square inches.
For a Trentham boiler, 8 or 10 ft. in length	400
For a saddle or similar shaped boiler, about 6 ft. long ..	320
" " about 4 ft. 6 in. long	250
" " about 3 ft. long or smaller	200

Other boilers can be computed from this with sufficient accuracy, but if there is the least doubt let the error be towards making the chimney a little larger, not smaller, as unless done intentionally, it would be unlikely that the chimney would be made too large.*

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* Boilers of a portable character, having no flues, can do with less chimney than any ; a short piece of pipe suffices if surroundings are favourable.

The sizes just given will be found rather full, as they are based upon the chimney being low—in fact, of the minimum height just referred to. If the chimneys are carried higher these areas can be reduced. As an instance it may be suggested that if a chimney is carried up double the minimum height, the area might be reduced one-fourth below the approximate sizes just given. When the chimneys are low they require to be of good size, quite roomy, and on no account must that point where the boiler flues join the chimney be choked, or have abruptly square angles.

In building works, the height of the chimney is rarely insufficient, as even with the attic fire-places we generally get about 10 feet from the grate opening to the outlet at top, at the least, and this is sufficient as we have no horizontal passages for the smoke to pass along (nor should we get the smoke to travel in that way as the grates are open). At the same time we have to remember that with open grates a better working chimney is needed than with closed stoves or boilers. Ten feet is sufficient, however, if the chimney terminates well above the building and the grate is of the recognised ordinary pattern.

The internal area of the chimneys of grates in a residence varies from 9 × 9, 9 × 14, to 14 × 14,† not a great difference as the size and character of the grates do not differ much. It is very odd to notice that although a builder in erecting a house always adheres to these sizes correctly, if he has to fit up a stove or heating appliance with a chimney wholly or partly of iron pipe, he is nearly certain to use a pipe of too small a size. This is rather a sweeping assertion, but it is most noticeably correct in quite the majority of instances for although, as just mentioned, the bricklayer puts a 14 × 14 or 14 × 9 inch chimney as being necessary for a fair sized grate, it is most unlikely that he would think of using a round iron pipe of 16 or 14 inch diameter. If this grate or stove had to be stood out and connected in this way, it is more probable that he would consider a 7 or 8 inch round pipe ample, these latter sizes having areas considerably less than he would give to the brick chimneys of attic grates.*

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* These remarks are based upon the supposition that the chimneys are of brickwork, this being usual with horticultural works. These areas are also supposed to be in conjunction with minimum heights. As an instance, a 36-inch saddle boiler would work well with a 10-inch chimney, if the latter was, say, 20 feet high.

† Not usually larger in modern residences.

Of course, smoke pipes are at any time objectionable-looking objects † and on this account are kept as small as possible to the prejudice of the stove, especially after soot has been deposited, which practically reduces the internal diameter. As a rule, a smoke pipe should never be less than 6 inches, the exceptions to this being small coke stoves such as the "Tortoise" and many other makes which will work with from 4 to 5-inch pipes; but for any stove burning about as much fuel as a dining-room grate the size should be nearer 7 or 8-inch; and if it be a grate—that is, open and not wholly closed—a 9-inch pipe should be used, this size being fully a third less than the brick chimney a builder would provide for it. There is no objection to making an iron smoke-pipe of a square section to make it appear less like what it is.

The chief trouble experienced with the low chimneys of horticultural works is down-draught due to their being lower than some surrounding object or objects, and the same remark applies to any residence chimney if it does not reach up as high as, and well above, the main building. This is often the case with the chimneys of what are called "back additions." This trouble is usually difficult of cure, as the downward deflection of the wind from over the higher object is not always steady; if it were, a revolving elbow or lobster back cowl on the top of the chimney to turn its back to the wind would be a perfect remedy, and it is often tried with success. If, however, the downward current of air is influenced by other surroundings it will act like a wind maelstrom, or in some such irregular and conflicting way that the major portion of the wind-guards and patent tops may prove useless. With horticultural works,* if this is the case, resort is usually had to the most simple chimney top, a conical cap, and better attention is given to the fire when the wind is in an objectionable quarter.

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* The writer met with an instance in which a large hall stove (one that could be converted from a close stove to an open grate, and consequently needed a larger chimney than one wholly closed) failed to work, and it was found to be connected with the brick chimney by a 4-inch round pipe. When the workman was remonstrated with he actually excused himself as being unaware that the stove wanted a specially large pipe. The stove had a 9-inch circular nozzle on it.

† These pipes will bear tasteful decoration in light water-colours, which last and keep in satisfactory condition. They are usually given a coat of black, with the worst results as to appearance.

When a chimney of a building is troubled with down-draught no half measures can be adopted as a small issue of smoke into a room causes injury to its contents and renders it uninhabitable. If the down-draught is of an intermittent character it is almost invariably caused by the chimney being insufficiently high, the trouble being noticed when the wind is in some particular quarter, and a certain remedy can only be looked for in making the chimney higher. It is not sufficient that the chimney top be as high as the building, it must be higher than the highest ridge, or trouble will ensue in almost every case; it should always be 6 feet higher, if possible.

Occasionally a chimney of good height and correct in general details will smoke and entail a great amount of trouble in ascertaining the cause, as nothing is visible from an ordinary inspection. Even in this case it may proceed from several causes, such as the displacement of a brick between it and another chimney.† It is usually very difficult to ascertain the exact position of such a fault, but the trouble itself can be discovered by placing a sack on the chimney top and watching if smoke still continues to go up the chimney. Or the trouble may proceed from a fissure caused by unequal settling down of the house; but generally it will be found to be due to a deficiency of air ingress to the apartment where the fire-place is situated.

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* Down-draught does occasionally occur with these works, but usually the glasshouses are well away from both high buildings and trees, and then the chimneys act normally.

† It is a wonder this does not occur oftener. Chimneys are divided from one another by 4½ inches of brickwork, and the sweep's appliances must exert a great force when they encounter a bend in the chimney.

This latter source of trouble is very common, yet little understood by the average workman, for it is somewhat puzzling unless the actual phenomena connected with the action of a chimney are clearly understood. The trouble is occasioned by a want of provision for the proper inflow of air into the apartment where the fire is, and without which a proper flow of air (the draught) up a chimney cannot take place. Although a chimney acts excellently as an exhaust or outlet ventilator it has none of the properties of an exhaust pump, and its up-current of air stops immediately the supply from which it maintains itself is stopped. In the usual way the supply of air to a fire is furnished by the crevices around the doors and windows, and it is when these are quite new and well fitted and kept closed that the trouble frequently shows itself, or when the tenant goes to great care in stopping all round these places with draught tubing, &c., to exclude draughts effectually. Of course, if the door was left open the trouble could not occur, but when fires are required open doors are generally vetoed.*

The effect of this is to make the chimney act as if it were possible for some chimneys to be devoid of the cause which promotes a draught; the smoke goes up most sluggishly (there being no agent to hasten and carry it), and some curls and oozes out into the room. Sometimes a very different effect is produced, for although the door by which the room is entered and the windows are tight closed, there may be communication between this room and another where there is another fire-place. In such a case (if there are no air entrances in that room) one chimney will help itself to the air it needs from the other, the strongest chimney having a fairly normal up-draught and the other having (while the doors are closed) a permanent down-draught. A lighted taper held at this fire-place will show that its down-draught is supplying the room and the other fire-place with air, and carries with it a most strong and objectionable odour of soot, if the chimney has been used. It is needless to add that the down-draught will not permit of a fire being lighted in that particular grate, unless the conditions are altered.

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* The writer met with a failure of this sort, but for which a local man recommended a certain kind of top to the chimney, "never known to fail." It did fail in a most pronounced way, yet the man must have had great faith in it, as from first to last he never went into the room where the troublesome fire-place was.

In many of the vast buildings now being erected the joinery work is very good, and as the apartments are arranged in "flats," the rooms opening from one into another, this trouble is of common occurrence, the fire-places being so far removed from the usual source of air, i.e. the entrance halls and corridors. Unless provision is made for supplying the chimneys with air they are almost compelled to have recourse to one another for it.

It will be understood that the remedy for this is to provide inlet ventilation. It is much needed, for other reasons, in rooms that are so ill provided with air as this. The Tobin's tube ventilators act well as they project the air towards the ceiling, but it must be mentioned that if no efficient outlet ventilation is made for the vitiated air and products that rise to the ceiling, this inflow of air will tend to bring them down to be respired again, assuming that it is a living room that is being treated.

This chapter will not permit of the subject of chimneys being treated at all exhaustively, but there is one other point that may be explained with profit to the reader, this being the occasional desirability or necessity of conveying smoke and products downwards from a fire, and horizontally under a floor, before they ascend normally in a chimney. This is commonly called, working a stove with "a descending flue," but the portion that actually descends is always very small, rarely more than 3 or 4 feet with a tall stove, but the horizontal portion under the floor may exceed this measurement very considerably.

The necessity for this arises when a stove, perhaps of a highly finished character, is stood in an entrance hall, in a position several feet away from a chimney, and in which a smoke pipe carried in mid-air or across the ceiling could not be tolerated. In such a case an elbow placed on the back of the stove and the pipe carried downwards and under the floor-level is resorted to with every success, the only necessary provisions being a sufficient height of chimney, a non-combustible floor, and access to the underground pipe for sweeping. Sometimes the horizontal pipe is carried right through the floor and suspended to the ceiling beneath, but in that case—and, in fact, in all instances—the pipe should be surrounded with some material (non-inflammable) which will prevent loss of heat, as we must under these somewhat unusual circumstances keep the chimney as efficient as possible.

This can be resorted to almost with impunity with close stoves so long as the vertical chimney is in height double the length* of the horizontal and descending flue, but in every case the joints must be made perfectly air-tight. With stoves or portable grates which have open fires more care is needed, as will be understood, and a greater allowance of vertical chimney must be allowed in proportion to the length of the horizontal pipe. As a rule these latter articles should not be so fixed unless the chimney is 2½ or 3 times the length of the horizontal and descending portions, and the necessity for perfectly tight joints becomes even more marked. The descending and horizontal flues require most particularly to be of full size, that is, equal in area to the vertical chimney. On no account should it be attempted to use small pipes with stoves or grates under these circumstances (see p. 541).

When the horizontal flue is of moderate or of full length, it usually becomes necessary to make some provision for warming the vertical chimney or inducing a strong draught in it before the stove can be lighted. It must be remembered that however efficient a chimney may be when receiving hot gases from a fire, this efficiency is very materially reduced when the fire is out and the draught is only due to the heat imparted to the air by the warmed brickwork. A draught caused by this latter means alone is not so strong that it can overcome serious obstacles and draw a volume of almost cold smoke downwards and along a horizontal flue. Usually a door, probably a sweeping door, is placed at the base of the vertical chimney,* and the required effect can be brought about by thrusting some lighted straw or shavings in at this point. If the works are on a somewhat extensive scale a small close stove called a "pilot" is fitted at this point, but this stove should only be lighted up when the other fire is being started, and after that it should be well shut off by a tightly fitting damper.

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* One and a half times will commonly do if the chimney is of ordinary efficacy, and a close-fire stove is used.

Where it is possible the underground flue is best made of earthenware pipes laid in concrete ; an earthenware pipe makes the very best of flues, and house chimneys are often made in this way, the pipe being imbedded in the brickwork.

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* If possible this should be a litlle *below* the point where the horizontal flue enters.

CHAPTER XXV.

VENTILATION.

Ventilation by natural or mechanical means—Quantity of air per person—Table of quantities for various requirements—Ventilation to living rooms—Extract flues—Table of velocities at different temperatures—Air propulsion—Relation of inlets to outlets—Points of entrance for cold or heated air.

THIS subject cannot very well be disassociated from that of heating, especially when the latter applies to building works. In places where large numbers of people congregate the subject of heating has of necessity to be considered in union with the subject of this chapter, for the ample ventilation needed in such instances will imperil the efficiency of the heating apparatus unless anticipated and allowed for.

The first practical consideration in ventilation is as to the quantity of air that should be taken from an apartment per minute (or per hour) per each person occupying it; to carry away all or the necessary quantity of impure and vitiated gases, &c., and so keep the air within the space fresh, agreeable to the occupants and not prejudicial to health. Very usually this is put about the other way, that is, the quantity of fresh air is spoken of as being introduced per person, but it must be submitted that this is not so correct. We shall get more certain results if we exhaust the room of the quantity laid down, provided of course there be inlets for fresh air, and that the exhaust be carried from a point where the vitiated air will readily pass into it.

There are, however, two ways in which ventilation is effected, viz. by natural means, i.e. gravity; or by some mechanical force. In the former the exhaust system applies wholly, by withdrawing air by means of flues, but with the latter the term exhaust cannot always be held to apply, as in many instances, fans or air-propellers are used to force air into an apartment, and the outlets are thus compelled to act, so to speak, by the force exerted through the inlets. The word *plenum* is associated with this plan of ventilation.

If we speak of the quantity of air *required* per person, we shall err, as from the suggested quantities about to be given, it will be seen that from 25 to 60 cubic feet is allowed to each person. No individual needs this quantity for respiration ; it represents the quantity that should be taken from the place per minute to carry away all noxious gases, that which is carried away being replaced by fresh air, which is afterwards rendered unwholesome, and carried away in its turn. The actual quantity of deleterious gases and exhalations given off by a person, or from gas-burners (the only two causes that have usually to be dealt with), is small, and no great degree of ventilation would be needed to remove it, if there was a means of carrying it off by itself. This, however, is impossible, for the gases and vapours so readily mix themselves with the purer air, and make it all of an equal degree of impurity ; constant and abundant renewal is therefore required.

There is a considerable diversity of opinion as to what quantity of air should be allowed to each person, or to each gas burner, in an apartment (small or large). The quantities that we get from various writers range all the way from 4 to 35 cubic feet for a man undergoing no particular exertion, and ranging as high as 70 cubic feet for places where the occupants are in exertion, causing exhalations, and respiring to the fullest natural extent, as in ball rooms, &c. For places where the exhalations from the persons of the occupants may be of a noxious character, as in some wards of hospitals, or in workshops of some particular trades, the highest quantity is allowed.

The quantities given are subject to variation in other ways, as for instance, women and children do not need such a great allowance as that given, which is for men ; the usual proportion is two-thirds for adult females and one-half for children of either sex. This allowance would apply to schools or any places devoted to women or children, but the minimum figures only apply to those who are in health, not engaged in active work or exercise, and the air not being tainted from any other cause. If, in allowing any of the quantities now given, the air of the room has a perceivable odour, however faint, it should be considered that the ventilation is inefficient. In public places and apartments where no particularly odoriferous calling is followed, every trace of odour should be removed, and in doing this we may safely consider that all objectionable or poisonous gases of an inodorous character have been removed also.* Odours are more readily contributed to the air by living beings in summer than in winter, and in these figures allowance is made for this.

The following Table shows approximate quantities of air per person that should be taken from a room occupied to its

	Cubic feet per minute.†
For ordinary living rooms, occupied by both sexes of all ages, average	30
„ sleeping apartments, ditto	25
„ schools—scholars of full age	25
„ „ infants	20
„ „ dormitories	20
„ workrooms, male workers, moderate exertion, air not vitiated by materials used ‡	30 to 35
„ ditto, ditto, but strong exertion	40 to 45
„ meeting rooms, public halls, lecture rooms	30 to 35
„ ball rooms	40 to 50
„ theatres, dining halls, &c.	30 to 35
„ hospitals, ordinary wards or exercise rooms	40
„ ditto, other wards where the dressing of wounds is done, and for infectious complaints §	50 to 60

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* Carbonic acid, the chief objectionable product of combustion, which we get from gas-burners, and also in quantity from our lungs (which are rightly likened to fires, as a similar process of combustion goes on), is inodorous. Almost the chief object of ventilation is to remove this gas.

† An anemometer is used to test this.

‡ In workrooms where odours, &c., arise from material used, no rule can be resorted to. Judgment or experiment must decide.

§ In instances where the ventilation is rapid, great care is needed in disposing the inlets to prevent draughts ; also the outlets, that the vitiated maximum (normal) capacity, the air inlet being sufficient, usual general conditions and no extraneous sources of vitiation.

The figures quoted are in addition to any natural means of ventilation that may exist, such as crevices around doors, &c., the occasional opening and shutting of doors or windows, or the existence of fire-place flues. It must be noted also that the quantities are approximate only, so very many circumstances being likely to exist to vary the amount to some extent. If others' calculations are found to disagree with these, it must be remembered that most probably no two ventilating engineers will be found to agree exactly in this respect, even if conditions are normal. If draughts are skilfully avoided and warmth (in winter) not sacrificed, it would be almost impossible to err on the side of too great a quantity of air, but of course an increase of ventilation, or what is the result of ventilation, usually means an increase of expense, both at first outlay and afterwards.

The methods of ventilation are practically confined to two, viz. flues which act naturally in withdrawing air from an apartment as a chimney does, the flue or flues having a draught by the warmth imparted to them by the vitiated air (or being warmed by a stove or a gas-burner, in which case the draught is more powerful); or, on the other hand, the change of air may be effected by mechanical means—by blower, fan, or air propeller, driven by steam or any other motive power.* The air is then either extracted from an apartment or forced into it, either way being efficient.†

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air may have instant escape, and not be carried about the room, and brought within other areas, in finding its way out. In hospitals the outlets should be numerous, as also the inlets.

* There can be obtained a small hydraulic motor suited for this purpose. It can be fixed at any point conveniently, a supply pipe to it, and a waste pipe from it, both small, being all that is needed.

† By extracting all vitiated air a good result is attained, but this may cause an inflow of new air to occur from many sources, not all specially provided, and not all above suspicion. By forcing air into an apartment the purity of its source is considered to be guaranteed, as it comes from one point which is carefully chosen. In the latter case there may be uncertainty as to all vitiated air being driven out.

In ordinary living apartments, the needed change of air is almost always effected by the fire-place chimney, and the badly fitting doors, &c. Sometimes ventilators are provided, but it is no uncommon thing to find them papered over or stopped in some way, for their cooling influence is objected to when the room is large and the fire only just capable of heating it without too lavish a degree of ventilation. Sometimes it is considered that to conserve the heat of a room saves the fuel, but the conservation of the heat in a general way can only be effected by retaining the noxious elements that we should make an effort to remove. The power of an ordinary open grate chimney is considerable, and amply sufficient for an ordinary room if under ordinary conditions; the objectionable gases, &c., could be removed from their place of lodgment in the upper part of the room by it, but this is not usually the case, and the aid of a ventilator is needed.

Still, referring to an ordinary living apartment, if we wish for an outlet ventilator to act as an outlet, with *certainty*, we must place it in a flue or chimney* which is a very efficient air-extractor. If we place a ventilator in an outer wall it will act as an inlet, if its construction will permit it, as, assuming there is a fire-place in the room, the chimney will be found to at once take part of its air supply from this opening. As a rule, all openings into a room, if they are not very numerous, or very large, will act as air inlets if there is a good chimney leading out of it, and this result is more certain when a fire is burning, and the draught at its strongest.

It would be difficult to make any simple rule as to the proper sized ventilators to be used for this purpose, as it would depend upon the number occupying the room when it contained its full complement (this, however, would permit of easy calculation), but more greatly upon the draught in the chimney. The extracting powers of ventilating flues, which are practically chimneys, will be spoken of presently, but complex calculations are hardly needed for such ordinary purposes as these. We are supposing a good chimney exists in a room; this is always sufficient to induce a free inflow of fresh air (inlets existing, either by crevices or provided) to keep it well supplied for respiration, and if by some simple means we take away the collection of heated and vitiated air near the ceiling the desired end will be attained. The size of a ventilator for this purpose* may be as follows:—Rooms about 10 feet by 10 feet, two, or perhaps three occupants, say, two gas-burners: ventilator 9 inches by 3 inches inside measure. Rooms about 16 feet by 12 feet, three, or perhaps four occupants, say, three gas-burners: ventilator 9 inches by 6 inches inside measure. Rooms about 20 feet by 16 feet, four, or perhaps five occupants, say, four gas-burners: ventilator 9 inches by 9 inches (or equal area). Larger rooms than the latter can have a single ventilator to carry off the upper air referred to, if the number of people be small, but with rooms that are larger than this two ventilators should be provided (if there is convenience for two) or some special means provided for carrying off the air from two or more points in the room. This is supposing that the room be really large, occasionally occupied by a numerous company, and having many lights to add to the volume of carbonic acid. Low rooms require more attention than high ones.

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* Of course, chimneys which have down-draughts cannot be utilised in this way.

Rooms in which there is no fire-place and its accompanying chimney, require very different treatment, for we lose a valuable assistant to ventilation when this is absent, and in treating such, the rule as to quantity of air per person, &c., on p. 549, must be considered in the first place, then the means of withdrawing the fouled and of introducing the fresh air in the proportion that the rule gives.

Where it is possible the most economical results (both in cost and attention) are effected by natural ventilation by means of flues provided in the building, these acting as extractors in the same way as chimneys. They, however, will not be so effective, that is, give such an extensive result as chimneys, unless they are artificially heated. This can be done, if the circumstances require it, by gas or a stove, at comparatively little cost and with little attention.

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* The ventilator to be inserted into the chimney of the room through the chimney breast, as near as possible to the ceiling. The chimney must be a normally effective one, of course, not suffering with down-draught, but regularly active in its work.

To arrive at the working value of a ventilating shaft, we cannot do better than have recourse to another of Hood's valuable tables, which he has compiled upon actual effective results, making all needed allowances. The temperature of the outer air and the temperature of the vitiated air passing into the flue need only be ascertained to put this rule to practice. It will be noticed that the doubling of the height of the ventilating shaft does not double its extracting power; this is due to loss of heat by the ascending air, and friction.

The following Table shows the quantity of air in cubic feet, extracted per minute by a ventilating shaft of which the area at the entrance (and not less at all points) is one square foot, the fresh air inlets being equal in area or larger :—

Height of Ventilating Shaft in Feet.	Excess of Temperature of Air entering the Ventilating Shaft, above the External Air.					
	5°	10°	15°	20°	25°	30°
10	116	164	200	235	260	284
15	142	202	245	284	318	348
20	164	232	285	330	368	404
25	184	260	318	368	410	450
30	201	284	347	403	450	493
35	218	306	376	436	486	531
40	235	329	403	465	518	570
45	248	348	427	493	551	605
50	260	367	450	518	579	635

As an example of the above let us suppose a ventilating shaft 30 feet high and the difference in temperature of the two airs to be 15°, then the discharge would be 347 cubic feet per minute; or if the height be 40 feet and the difference in temperature 20° then the discharge would be 465 cubic feet per minute.

Let it be clearly understood that the height of the ventilating shaft will be governed by the height of the building, not by the requirements, for unless this be done we must not expect efficiency. These flues are governed by precisely the same rules as fire chimneys, and may be subject to down-draughts and other ill effects from the same causes, which would utterly destroy their efficacy (see Chimneys). If flues are carried horizontally to any extent their efficacy is lowered.

In calculating the area of an extracting flue it must be remembered that it is at its greatest efficiency in winter, when the outer air, which actually causes the draught in the shaft, is coldest, the greater degree of specific gravity between the two giving the greater effect, as the table shows. Consequently the area should be calculated upon summer ventilation. At the same time, however, we do not get air vitiated by gas to the extent in summer that we do in winter, unless the rooms be chiefly occupied late in the day or night. If the area of the ventilator for the summer be too great for the winter this can be regulated by the mechanism of the ventilator itself, as it is not supposed that the shaft terminates in the room by a mere hole.

In very hot weather, in crowded places, the extracting shaft is not usually sufficient if left to operate by the mere difference in the temperature of the fresh and vitiated air, for at this time the difference is very little. Even if the area of the shaft was made unusually great it would not suffice for such a number of people as we get in a theatre, so it is better to have the shaft of reasonable size, and heat and rarefy the air passing into it. In theatres this is usually done by the central sun-burner, and the ceilings of such places are constructed of a shape adapted to a good end, curving upwards towards the centre where the extracting opening is. This arrangement of ceiling is undoubtedly a great advantage and goes far towards giving perfect results.

Occasionally, in very large undertakings, an independent shaft has been erected, that is, at the side, but not necessarily within the building, and the air within the shaft rarefied by a large coke fire at the base, which would induce a strong up-draught within it like a chimney. Into this shaft would be connected the extracting flues from various rooms or places, and the draught of the shaft would confer its power upon these flues and make them of proportionate power in conveying the vitiated air as required. This plan, and, in fact, any plan of utilising one shaft for many minor ones, has the disadvantage of causing these latter to work unequally, supposing they do not all proceed from the same level. It is better, wherever possible, to have separate shafts for different floors of a building, or if one shaft, let it be divided in some way (lengthwise), and so be converted into two or more as needed.

The mechanical means of ventilation are confined to those contrivances which propel air, either propelling the exhaust outwards, in which case the air passes into and through the air inlets naturally, or propelling the fresh air inwards, in which case, the outlets act by the pressure of the incoming air forcing outwards that which is already in. There are several forms of these contrivances, the majority of them being termed "air-propellers,"* and are open fans, in contradistinction to those which expel the air through an orifice and are commonly termed "blowers." It is unnecessary in this short chapter to enter into the effected value of the vanes, their size, shape, or angle, as it is not supposed that the engineer himself proposes to make these appliances, and the maker's guaranteed values can be looked to for this. When the quantity of air is known the maker can be relied upon to furnish what will propel this amount effectually, the general conditions being correct. When an air-propeller is used, the height of the vitiated air shaft, or openings, is not of such moment as with flues actuated by the rarefaction of air; down-draughts, &c., not producing any noticeable ill effect.

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* The Blackman air-propeller is illustrated on p. 405.

The air inlets are next to be considered ; they must have relation to the outlets, or the effectiveness of one or the other will be imperilled. The air inlets must be fully large, the minimum being the same area as the outlet or outlets, but a little larger is always preferable. The inlets are spoken of in this plural sense, as it is nearly always necessary to have more than one, although perhaps the air may be in some instances conducted to the apartment by a single conduit. If we bring the whole of the air in at one point we may not succeed in equally distributing it, so that at some parts of a large apartment the air may tend to be stagnant to some extent—at any rate, more than at other parts, depending upon various circumstances. What is worse, if the inflow is in good volume, for a large place, we should introduce a draught that would be intolerable, for although air readily diffuses itself in the usual way, we shall not get this agreeable diffusion when the air has attained momentum. Thus it is necessary in practically every case to break up and distribute the incoming air to the greatest extent possible.

If the inlet air be warmed by any of the processes described in the previous chapters, the draughts lose their objectionable features, or at least they are minimised, but still the inflow should be broken up and made as equal as possible at all parts, for reasons that will now be understood. It is understood that heated air (inflow) can be induced to travel simply by its rarefaction, but the force it exerts in thus urging itself into the room is not sufficient to make simple openings in walls act as outlets, there must be extract ventilating shafts.*

There is a greater diversity of opinion than ever as to where inlets should be situated, high up, low down, or midway. A great number are in favour of introducing the new air at a high point, the contention being that if low, draughts are created, dust carried up, and the lower part of the room and the body kept cold as the warmed air immediately rises and passes away, and the cold air as immediately flows in, and so it proceeds perpetually, the lower part of the room never having a chance to get warm. This is very good as regards inflow of cold air and in winter, but if the air be warmed, or if it be sultry weather, the argument is rather at a loss. If we introduced warmed air near the ceiling and the extract shaft opened at that point also, it would be to the prejudice of the lower part of the room, as we may consider the room would not be so air-tight that cold air would not be entering somewhere.

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* In ordinary living apartments of medium and small size, the fireplace chimney is the active ventilator, as already explained.

If the room be heated by hot water radiators, the introduced air might be cold, and in this case if brought in through or between the heated tubes (being warmed by them) it should come in at a low point through gratings in the floor or the skirting; but if the air is not warmed it should be brought in nearer the ceiling or through ventilating tubes (Tobin's tubes), which project the inflowing air upwards to prevent draughts. If these tubes are not used the cornice can be adapted for the purpose in view, but the air must be led to enter at many points, and even at these points cold air should be made to encounter some obstacles to break its momentum, to spread it, or reduce it to threads.

The particular objection raised to bringing in cold air near the ceiling, is that so soon as it has lost its momentum, it commences, by its superior gravity, to sink (this is desirable); but it has, by coming in contact, also cooled some of the carbonic acid* and other bad gases which always rise to the ceiling, and by thus increasing their gravity brings them down to be again respired. In other words, it brings down some of our breath to be breathed again, a thing that every one considers to be wrong.

There is much to be said in favour of bringing in the fresh air (if cold) at an intermediate distance just above people's heads, but in doing this, there must be no inrush, it must be brought through fine perforations, and then it should be first deflected to and fro to break the current.* If the place be large some must necessarily be brought centrally, and this

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* Of carbonic acid and air, at the same temperatures, the former has the greatest weight, and would fall more quickly than air. See Appendix, Table XIII.

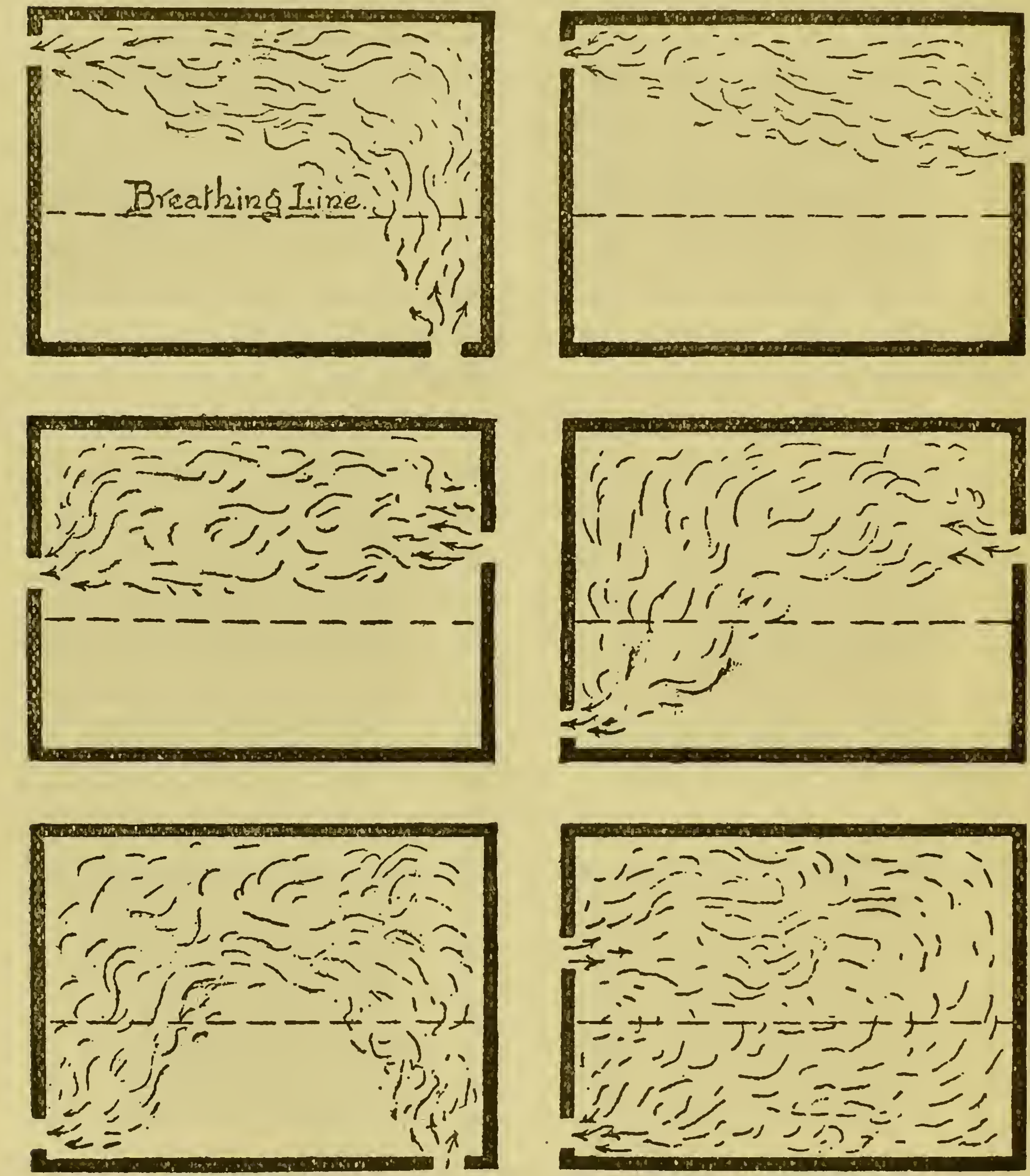

Fig. 369.

cannot usually be done except through the floor, in which case it should be warmed, but still distributed to as great an extent as possible to prevent currents.

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* We cannot very sensibly break up a strong current except by distributing in several directions simultaneously ; it is better to do it by increasing the number of points of inlet.

There are just a few advocates for introducing (in ordinary living apartments) warm air, heated in an air chamber at the back of the fire-grate. This heated air is brought in at the ceiling, the *whole* of the extract work being done through the grate entrance to the chimney. By this arrangement we may suppose that all vitiated air and gases from the occupants of the room are carried downwards as exhaled, by the perpetual down current of air that must be supposed to exist, and so far the results would be efficient. But what becomes of the oftentimes greater bulk of noxious gases that are caused by burning gas? These must be carried down too, and it may be imagined that a person sitting close to the fire-place would have all the ill products that are generated in the room carried past him in their passage to the chimney.

In an American work* before the writer, there are given the results of some interesting experiments conducted with the view to determine the best positions for the inlets and outlets to occupy in rooms heated by warm air. The effects obtained by locating the apertures at different points were made visible by mingling smoke with the inflowing warm air, and illustrations as at Fig. 369 are used to describe the results observed. The inflowing air-stream was regulated to the normal speed for warm air entering by force of gravity alone, this speed admitting of successful diffusion and an absence of distinct currents or draughts. The conclusion arrived at in this case favoured an inlet a little above the breathing line with outlet in floor or at floor level; both to be on same side of room, as centrally situated as possible.

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* Carpenter's 'Ventilation and Heating.'

CHAPTER XXVI.

THE METROPOLITAN BUILDINGS ACT. ITS APPLICATION TO HOT WATER, STEAM AND HOT AIR WORKS, AND TO CHIMNEYS AND SMOKE FLUES.

THE object of this paper is to be a ready reference for those engaged in these works, as reference should be made with all new undertakings. To commit the whole to memory is neither convenient nor usual, except a person be engaged in all branches of these works perpetually. Another reason for treating this subject is to make as clear as possible what the Act requires, and to point out what have been unreasonable and perplexing features, and also the arbitrary constructions that surveyors can put upon the readings, if so desired. The various sections are as follows :—

M.B. ACT (18 & 19 VICT. CAP. 122), 1855.

Sec. XX., sub-sec. 11 : There shall be laid level with the floor of every story, before the opening of every chimney, a slab of stone, slate, or other incombustible substance, at the least 12 inches longer than the width of such opening, and at the least 18 inches wide in front of the breast thereof.

Do. ; sub-sec. 12 : On every floor, except the lowest floor, such slab shall be laid wholly upon stone or iron bearers, or upon brick trimmers ; but on the lowest floor it may be bedded on the solid ground.

Do. ; sub-sec. 13 : The hearth or slab of every chimney shall be bedded wholly on brick, stone, or other incombustible substance, and shall be solid for a thickness of 7 inches at the least beneath the upper surface of such hearth or slab.

Do.; sub-sec. 17: No timber or woodwork shall be placed: In any wall or chimney breast nearer than 12 inches to the inside of any flue or chimney opening.

Sec. XXI. The following rules shall be observed as to close fires, and pipes for conveying heated vapour or water; that is to say:

1. The floor under every oven or stove used for the purpose of trade or manufacture, and the floor around the same for a space of 18 inches, shall be formed of materials of an incombustible and non-conducting nature.
2. No pipe for conveying smoke, heated air, steam, or hot water shall be fixed against any building on the face next to any street, alley, mews, or public wall.
3. No pipe for conveying heated air or steam shall be fixed nearer than 6 inches to any combustible materials.
4. No pipe for conveying hot water shall be placed nearer than 3 inches to any combustible materials.
5. No pipe for conveying smoke or other products of combustion shall be fixed nearer than 9 inches to any combustible material.

And if any person fails in complying with the rules of this section he shall for each offence incur a penalty not exceeding twenty pounds, to be recovered before a Justice of the Peace.

AMENDMENT ACT (45 VICT. CAP. 14), 1882.

Sec. XVI. From and after the passing of this Act the restrictions imposed by the twenty-first section of the Metropolitan Building Act, 1855, with respect to the distance at which pipes for conveying hot water or steam may be placed from any combustible materials, shall not apply in the case of pipes for conveying hot water or steam at low pressure.

From Sec. XX., sub-sections 11, 12 and 13, we learn that every grate, stove, or cooking range in a building shall stand upon a hearth of non-combustible materials, which hearth must measure at least 1 foot wider than the opening in which the appliance is placed; it must extend at least 1 foot 6 inches beyond the front of the chimney breast, and it must be at least 7 inches thick.

In fixing the width and front extension of the hearth, the supposition was that the stove, grate, or range would occupy the whole width of the opening, as is most usually the case, and it would not extend or project out beyond the level of the front of the breast. This latter is frequently departed from, but no provision is made to meet it. In the strict letter of the Act, no objection could be raised to a stove which, if placed in the opening, projected well into the room, even close up to the floor boards,* no mention being made of the hearth extending 18 inches *in front of the stove.* Although a measurement of 18 inches for both the width and front extension is mentioned in the first sub-section of Section XXI., this could not be held to apply, as it restricts itself to trade and manufacturing purposes. District Surveyors, however, hold that the Act intends the front and side extensions of the hearth to be beyond the heating or cooking appliance, and their decision is a sound one, although not directly implied in the Act.

As to the thickness of the hearth, 7 inches is sufficient for what this portion of the Act refers to, viz. grates for warming rooms, and kitchen ranges, as the thickness mentioned, whether of stone, brickwork, or concrete, will ensure solidity and the like, but, for this small purpose, the Act clearly says that this hearth must not be supported on woodwork. A little inquiry would elicit the fact that there are countless numbers of hall stoves, stoves in other situations, and portable kitchen ranges fixed and working, standing out in the hall or room, not within a chimney opening, but having connection with the chimney by a pipe. If any of these stoves are on a ground or basement floor with the hearth just beneath, there may not be any wood beneath them, but if the floor has rooms or cellars beneath, there can be every assurance that the hearth (or what in this instance is called a base) rests upon woodwork. Not one person in a hundred would dream of cutting through the floor, the joists, and the ceiling below, and go to the great cost of inserting iron or other incombustible supports for the base upon which the stove is to stand, when perhaps the value of the little stove may be one pound.* In the first sub-section of Section XXI., just referred to, and which applies to trade and manufacturing purposes, an aggregate thickness of 18 inches is mentioned without any suggestion as to the nature of the supports. In this case (in which we may suppose far greater heat is experienced) it can be assumed that wood may exist beneath this 18 inches of material.

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* A Fire Insurance Company might reasonably object.

Very commonly, small stoves and portable cooking ranges are fixed on a stone or concrete base, resting upon a wood floor, this base being 7 inches thick, 1 foot wider than the stove or range each side, and projecting beyond the extreme front of the stove or range 18 inches. This complies with the requirements of practically all the Fire Insurance Companies. Surveyors will commonly pass it (although they can object if they wish to be arbitrary), and it can be looked upon as *perfectly safe.* It will be noticed that it complies with the terms of the Act in every way except as to what the hearth is supported upon.

The extension of the hearth in front of a grate or stove, which must be 18 inches at the least, should have a fender or a curb, or a boundary of some incombustible material provided ; without this, the extension named is insufficient for safety, more especially in a kitchen where a fender or curb is not always used. The live fuel which drops from the range fires, having a little distance to fall, readily bounds or is projected into the room, sometimes to a considerable distance.* With living-room grates, fenders or curbs are always used, and thus no harm results, but in kitchens the front extension of the hearth should be 3 or 4 feet; there can be no objection to this, as, supposing the kitchen is not on the ground floor, the additional cost would not be at all serious even in small property.

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* Perhaps this sort of thing is left to the discretion of the district surveyors; this would suffice if their discretion was always the same, and always practical and unbiassed, but in no two districts do the surveyors have a discretion that is of the same degree or character. It is hardly to be expected, and it is tremendously awkward to the stove and range fixer, who has business in all districts, and for him the Act might as well not exist.

In sub-sections 3, 4, and 5 of Section XXI., pipes for the conveyance of hot air, steam, hot water and products of combustion (pipes from coal or coke-burning stoves, &c.) are dealt with. Now heated air, and steam under pressure, are treated alike as to the least distance they must be from woodwork, viz. 6 inches, but although hot air is decidedly able to cause ignition to ordinary combustible substances, steam at high pressure would not even scorch or discolour them unless it were superheated. Thus the distance for steam pipes, even with steam at high pressure, could well be reduced. In residence works, where high pressures are not attained, the lessened distance would be a boon in reducing, firstly, cost in supporting the pipes, and, secondly, their unsightliness. With hot-air pipes, 6 inches is barely sufficient close down by the furnace. With a stove of the "cockle" variety, it is possible by careless firing to raise the temperature enormously, and although 6 inches is sufficient distance to prevent actual ignition, it will permit of the materials getting into such a state that a lucifer match would complete the mischief. If they be papered surfaces the paper may split and curl off and come in contact with the pipe, and similar results might accrue from other substances. As the pipe gets away from the stove the heat becomes lessened (unless it be covered with some non-inflammable and poor heat-conducting material, when it would be rendered safe in another way) and a 6-inch limit would suffice after, say, the first 15 feet.*

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* Nearly every one has had experience of this, floor-cloth and mattings being burnt with holes, and in houses where the ranges are large the floor-boards in front of the fire-place have numbers of burnt marks upon them. This is just as likely to happen and cause serious results at night, if a fire is left the last thing.

Sub-section 4, which required a space of 3 inches between hot-water pipes of every description and adjacent woodwork, has been partially amended, as was very necessary, and will be referred to again directly.

Sub-section 5 deals with pipes (made of any material), which convey smoke and products of combustion—in other words, stove-pipes. The limit of 9 inches space between a smoke-pipe and inflammable material is decidedly insufficient with horizontal pipes carried beneath ceilings ;† although perfectly safe when working normally they would be highly dangerous if allowed to get foul (for there is no restriction as to the length of time which they are to go unswept) and so caught alight. In such a case as this, the pipe, if of sheet iron,‡ would get red-hot and remain so some time, as the soot collects so abundantly in horizontal flues and more particularly in sheet-iron pipes, with which the outer cooling influence augments the deposit considerably.

It seems a little odd that so low a limit should be set when sub-section 17 of Section XX. says, "No timber or woodwork shall be placed :—In any wall or chimney breast nearer than 12 inches to the inside of any flue or chimney opening," thus increasing the distance to 12 inches ; and this space being of solid brickwork would keep the woodwork from reaching a temperature of 100°, from an ordinary house chimney, such as here meant, even if the chimney were on fire.

With a chimney pipe of sheet iron we have a more dangerous thing than a hot-air pipe, from its liability of getting fouled by bituminous fuels. When this soot deposit gets fairly alight we experience a heat as great as from fire, sheet-iron enclosure being as nothing, and on this account a pipe of this description should be treated as a stove, so far as distance from inflammables is concerned.*

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* If the air in the pipe was heated by hot-water pipes, no space at all would be needed, although the Act makes no distinction.

† Match-lined in particular.

‡ If an earthenware pipe, as sometimes used, it would most probably fracture, and so be more dangerous.

The Amendment Act of 1882 contains the clause given on p. 564, referring to pipes conveying steam or hot water, it having been urged that sub-section 4 of Section XXI. of 1855 was unreasonable, and, if insisted upon, created unnecessary expense and trouble, and thereby caused a deal of friction in the working of the Act. It was not thought desirable to extend the Amendment to all such pipes, that is, not to those for high-pressure steam, or to those of Perkins' high-pressure circulating apparatus, or to any erected upon this system or its modifications; consequently the Amendment and its liberty from all restrictions only applies to hot-water and steam pipes at low pressure.

This Amendment has been acceptable, but has introduced one of the most annoying and perplexing things that could be imagined, as no really practical meaning can be attached to the words "low pressure." Surveyors are here again all inclined to put different meanings to it; some are as lenient as others are vexatious. There is no doubt that when this clause was framed it was understood that "low pressure" was a common term bearing a commonly understood meaning, and it is possible that in and about England there are districts where the term may have a regularly accepted construction, but it can be confidently asserted that an accepted meaning is not universal, nor is it general.

Some surveyors contend that "low pressure" applies to steam or hot water apparatus that have a maximum attainable temperature of 212°. This contention, with all respect to those who hold it, is utterly absurd, as it is hardly possible to have a hot water apparatus † that would not register a higher temperature than this down close to the boiler. If the apparatus only extended 10 feet high we could get 220° close to the boiler, and with increased height we could get increased temperatures (see High Pressure and Table I. of Appendix). If we are bound to 212° * the Amendment is useless: only in open vessels or a boiler with an open and empty expansion pipe from it, can we say 212° is the very highest we can get. If we had a closed boiler and arranged to fill up the expansion pipe but a few inches we should come outside the Amendment if that is its meaning, for by these few inches a certain weight would be pressing on the water below, and the temperature would rise, only a fraction of a degree, and perhaps hardly perceptible, but nevertheless positive. The water in a vessel must be absolutely free from pressure or weight exerted upon it to ensure its keeping down to 212° when it boils; indeed, if perchance the vessel itself was a very high one we could get a greater temperature at the bottom of it, without filling up a pipe.

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* It will be understood these are merely suggestions; the Act gives the *least* distance; when a doubt is felt the Act places no limit to a greater distance, and as a rule 15 inches is better, usually making no difference in cost of works.

† This does not refer to a sealed apparatus, but to the ordinary domestic kind, either for warming or draw-off purposes, with open expansion or air pipes.

It has been explained more than once in this book, that with a hot water apparatus extending up one or more floors of a building a great pressure or strain is brought to bear, particularly in its lower parts, by the pressure, or rather the mere weight, of the water that it contains. The boiler, which is the lowest point and has the greatest strain, has to withstand and bear a pressure of 1 lb. to the square inch for every 2 feet 4 inches † that the apparatus extends above it, calculating vertically to the highest point to which it contains water, this strain being exerted whatever be the size or quantity of the pipes, &c. Now, if we have an ordinary domestic apparatus in a large house extending up and containing water to say 50 feet above the boiler, we shall get a pressure at the lowest point of fully 21 lbs. to the square inch,

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* As a general rule hot water apparatus, either for domestic supply or for heating, and having an open expansion pipe, are passed by surveyors as coming within the meaning of the term "low pressure."

† Exact measurement is given in footnote under Low-Pressure Building Works.

and by referring to Table I. in the Appendix we shall find that water having this pressure upon it * will reach 260° before it boils and ceases to rise in temperature. In a hot water apparatus with an open expansion pipe the temperature would vary throughout its height, being highest at the bottom and decreasing upwards.

This is a long explanation, perhaps, but a desirable one in order to make the peculiarity of the term "low pressure" understood. Sometimes, in fact commonly, a surveyor or other authority will call any apparatus having an open expansion pipe, low pressure, and coming within the meaning of the Amendment; this is very reasonable, but does not convey any exact interpretation.

In its application to steam pipes the trouble is just as great—perhaps even more so. For what is the universal meaning of steam at "low pressure"? There is none. It may mean exhaust steam, commonly used for heating, the service ending in an open pipe, and therefore causing no pressure in the proper meaning of the word. More probably there was some limit of pressure intended which would be properly considered to be low. However, as the writer is informed,† different people who survey such works, and, so to speak, administer the Act, allow pressures varying from 5 lbs. to 30 lbs. as being within the meaning of the Amendment; but no reasons are assigned for the limitation of pressure that is made.

From somewhat lengthy experiments made by the writer, it was found that a temperature of 600° communicated to iron directly from the fire was insufficient to ignite paper, shavings, or splintered pieces of wood (deal); the paper was discoloured, but after subjecting it to a still higher temperature, about 650°, ignition did not take place. Thus so far as fire from ignition

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* It matters not how the pressure is exerted, the effect is the same.

† The writer is greatly indebted to Mr. Arthur Harston, F.S.I., for much valuable information and many practical suggestions, it having fallen to that gentleman's lot to unravel many knotty points and have great experience in this direction.

was concerned there was perfect safety ; but it will be understood that these materials were rendered in a very prepared state for being lighted if an already lighted substance was brought into contact. Even if woodwork, &c., were allowed to get into this state it would be no greater, if as great, a source of danger as the baskets or boxes of straw and shavings that lie about in nearly every residence cellar and in some lumber rooms, &c.

From these experiments a very certain conclusion could be drawn that a temperature of 350° would be perfectly safe for steam or hot-water pipes in contact with woodwork, and this temperature would not be a dangerous assistant to a fire arising from any other cause. These temperatures would then cover any domestic supply or heating apparatus (with an open expansion pipe) that is likely to be erected ; it would also cover those high-pressure works in which a regulating valve is used, and it would also cover all steam works where the steam is not superheated.

The reason for advocating the exemption of pipes up to this temperature is that in many works, in fact all those in residences and the like, the 6-inch and 3-inch distances of Section XXI. are very objectionable, adding to the cost very materially. Where the pipes are in sight special brackets have to be provided, creating unsightliness, and where the pipes are carried behind or beneath woodwork the provision for the needed space entails a great amount of work and expense in very many ways.*

It is noticeable that the Act and its Amendment make no mention of covering these various pipes with any material to conserve their heat and so permit of their nearer approach to woodwork when circumstances make it particularly advantageous and desirable, as very often happens. Perhaps when the Act was drawn a hesitation was felt in naming a material, but no doubt need be felt now, as we have the very thing in silicate cotton. It is non-inflammable, therefore suited for water or stove pipes ; cheap, and therefore applicable to all works ; very easily applied ; having many minor features to its credit, and being in favour everywhere.* If it were ever desired to reframe the Act, it would be a great boon to make a provision this way, allowing certain reductions in distance if this material were used in a certified thickness. For instance, if it were thought undesirable to allow high-pressure water and steam pipes to have actual contact with wood, a quarter inch of silicate cotton interposed between the pipes and woodwork would make them perfectly and absolutely safe. Engineers would not object, as a covering of this material to their pipes ensures better results in the apparatus, as has been fully explained elsewhere. Smoke and hot-air pipes would come within its application, and in some cases ensure decided advantages.†

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* With the high-pressure system, the pressure not limited by a valve, the space might be safely reduced to 1 inch, and prove a great convenience and advantage in many ways.

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* It has been mentioned elsewhere that from experiments quite recently conducted, silicate cotton, of all *non-inflammable* substances, had the least heat-conductive properties.

† An experiment was made with a thickness of silicate cotton of 1 inch, rather tightly packed, placed tight against a surface at bright red heat, about 1550°, for 30 minutes; at the end of this time the outer side of this material was only about 180°, almost bearable to the hand. No currents of air existed to have a cooling influence.

The London Building Act (57 and 58 Vict. cap. 213), 1895, now defines the term "low-pressure" as being applicable to "a hot-water or a steam apparatus having a free blow-off." By free blow-off is meant of course an open expansion pipe.

APPENDIX.

TABLE I.—TEMPERATURES THAT CAN BE ACQUIRED BY STEAM OR WATER AT CERTAIN PRESSURES; OR, A TABLE OF THE FORCE EXERTED BY STEAM OR WATER WHEN IN CONFINEMENT, AND AT TEMPERATURES ABOVE 212° F.

Heat in degrees of Fah.	Pressure.		Heat in degrees of Fah.	Pressure.		Heat in degrees of Fah.	Pressure.	
	Atmospheres.	lb. per sq. in.		Atmospheres.	lb. per sq. in.		Atmospheres.	lb. per sq. in.
212	1	15	275	3	45	393	15	225
216	—	16·5	294	4	60	399	16	240
220	—	17·7	308	5	75	404	17	255
225	—	19·5	320	6	90	409	18	270
230	—	21·5	332	7	105	414	19	285
235	—	23·6	342	8	120	418	20	300
240	—	25·8	351	9	135	439	25	375
245	—	28·1	359	10	150	457	30	450
250	2	30·9	367	11	165	473	35	525
255	—	33·6	374	12	180	487	40	600
260	—	36·1	381	13	195	511	50	750
265	—	39·0	387	14	210	531	60	900
270	—	42·1						

TABLE II.—QUANTITY OF VAPOUR CONTAINED IN ATMOSPHERIC AIR AT DIFFERENT TEMPERATURES, WHEN SATURATED.

Temperature of the air. (Fah.)	Quantity of Vapour per cubic foot in Grains Weight.	Temperature of the air. (Fah.)	Quantity of Vapour per cubic foot in Grains Weight.	Temperature of the air. (Fah.)	Quantity of Vapour per cubic foot in Grains Weight.
20°	1·52	48°	3·94	76°	9·38
22	1·64	50	4·19	78	9·99
24	1·76	52	4·46	80	10·59
26	1·89	54	4·77	82	11·29
28	2·03	56	5·06	84	11·98
30	2·16	58	5·40	86	12·68
32	2·31	60	5·76	88	13·36
34	2·43	62	6·12	90	14·15
36	2·62	64	6·50	92	14·93
38	2·80	66	6·91	94	15·81
40	2·99	68	7·31	96	16·76
42	3·21	70	7·77	98	17·83
44	3·45	72	8·27	100	19·00
46	3·69	74	8·80		

The capacity of air for water is about doubled by each increase of 27° F.

Table III.—Expansion of Air and other Gases by Heat, when perfectly free from Vapour.

Temperature (Fah.)	Expansion.	Temperature (Fah.)	Expansion.
32°	1000	100°	1152
35	1007	110	1178
40	1021	120	1194
45	1032	130	1215
50	1043	140	1235
55	1055	150	1255
60	1066	160	1275
65	1077	170	1295
70	1089	180	1315
75	1099	190	1334
80	1110	200	1354
85	1121	210	1372
90	1132	212	1376
95	1142		

Table IV.—Velocity of Chimney Draught at Different Temperatures, the External Air being at 32° F.

Temperature of warmed air. (Fah.)	Relative Velocity.	Temperature of warmed air. (Fah.)	Relative Velocity.	Temperature of warmed air. (Fah.)	Relative Velocity.
86°	4·93	230°	7·48	374°	8·14
104	5·51	248	7·62	392	8·17
122	5·98	266	7·73	410	8·20
140	6·35	284	7·83	428	8·23
158	6·66	302	7·92	446	8·25
176	6·92	320	7·98	464	8·26
194	7·13	338	8·05	482	8·27
212	7·33	356	8·09		

At the temperature of 482°, or just thereabouts, the velocity ceases to increase, and at higher temperatures it actually decreases, owing to the very great expansion of the air.

TABLE V.—SPECIFIC GRAVITY AND EXPANSION OF WATER AT DIFFERENT TEMPERATURES.

Temperature, Fahr. Scale.	Expansion.	Specific Gravity.	Weight of 1 Cubic Inch in Grains.	Temperature, Fahr. Scale.	Expansion.	Specific Gravity.	Weight of 1 Cubic Inch in Grains.
30°	·00017	·9998	252·714	121°	·01236	·9878	249·677
32	·00010	·9999	252·734	124	·01319	·9870	249·473
34	·00005	·9999	252·745	127	·01403	·9861	249·265
36	·00004	·9999	252·753	130	·01490	·9853	249·053
38	·000002	·9999	252·758	133	·01578	·9844	248·836
39	·00000	1·0000	252·759	136	·01668	·9836	248·615
43	·00003	·9999	252·750	139	·01760	·9827	248·391
46	·00010	.9999	252·734	142	·01853	·9818	248·163
49	·00021	·9997	252·704	145	·01947	·9809	247·931
52	·00036	·9996	252·667	148	·02043	·9799	247·697
55	·00054	·9994	252·621	151	·02141	·9790	247·459
58	·00076	·9992	252·566	154	·02240	·9780	247·219
61	·00101	·9989	252·502	157	·02340	·9771	246·976
64	·00130	·9986	252·429	160	·02441	·9760	246·707
67	·00163	·9983	252·349	163	·02543	·9751	246·483
70	·00198	·9981	252·285	166	·02647	·9741	246·233
73	·00237	·9976	252·162	169	·02751	·9731	245·982
76	·00278	·9972	252·058	172	·02856	·9721	245·729
79	·00323	·9967	251·945	175	·02962	·9711	245·474
82	·00371	·9963	251·825	178	·03068	·9701	245·218
85	·00422	·9958	251·698	181	·03176	·9691	244·962
88	·00476	·9952	251·564	184	·03284	·9681	244·704
91	·00533	·9947	251·422	187	·03392	·9671	244·446
94	·00592	·9941	251·275	190	·03501	·9660	244·187
97	·00654	·9935	251·121	193	·03610	·9650	243·928
100	·00718	·9928	250·960	196	·03720	·9640	243·669
103	·00785	·9922	250·794	199	·03829	·9630	243·410
106	·00855	·9915	250·621	202	·03939	·9619	243·151
109	·00927	·9908	250·443	205	·04049	·9609	242·893
112	·01001	·9901	250·259	208	·04159	·9599	242·635
115	·01077	·9893	250·070	212	·04306	·9585	242·293
118	·01156	·9885	249·876				

TABLE VI.—EFFECTS OF HEAT.

	Fahr. °
Temperature of a blast furnace	3280
Cast iron melts	2786
Gold ,,	2016
Copper ,,	1996
Silver ,,	1873
Bronze ,, (copper 15, tin 1)	1750
Brass ,, (,, 3, zinc 1)	1690
,, ,, (,, 2, ,, 2)	1672
Bronze ,, (,, 7, tin 1)	1534
,, ,, (,, 3, ,, 1)	1446
Metal, dazzling white heat (Pouillet)	2732
,, white ,, ,,	2552
,, dark orange ,, ,,	2012
,, cherry red ,, ,,	1652
,, dull red ,, ,,	1292
,, incipient red ,, ,,	977
Charcoal burns	802
Zinc melts (Davy 680°) Daniell	773
Mercury boils (Dalton)	660
Lead melts	612
Steel becomes dark blue	600
,, ,, a full blue	560
,, ,, blue	550
,, ,, purple	530
,, ,, brown with purple spots	510
,, ,, brown	490
,, ,, a full yellow	470
,, ,, a pale straw colour	450
,, ,, a very faint yellow	430
Bismuth melts	476
Tin melts	442
Tin 3 + Lead 2 + Bismuth 1, melts	354
Tin 2 + Bismuth 2, melts	283
Sulphur melts	218
Bismuth 5 + tin 3 + lead 2, melts	212
Wax melts	149
Acetic acid congeals	50
Olive oil ,,	36
Milk freezes	30
Vinegar freezes	28
Mercury congeals	−39

TABLE VII.—HYDRAULIC MEMORANDA.

A cubic foot of water weighs	62·32 lb.
A ,, ,, ,, contains	6·232 gals.
A ,, inch ,, weighs	·03616 lb.
A cylindrical foot of water weighs	48·96 lb.
A ,, inch ,, ,,	·0284 lb.
An imperial gallon contains	277·274 cub. in.
An ,, ,, ,,	·16045 cub. ft.
An ,, ,, weighs	10 lb.
A column of water 12 in. high, 1 in. square weighs	·434 lb.
A ,, ,, ,, ,, ,, ,, contains	·0434 gal.
A ton of water contains	35·84 cub. ft.
A ,, ,, ,,	224 gal.
Cubic feet × 6¼ (nearly exact)	= gal.
Gallons × ·16	= cub. ft.
Expansion of water heated from 40° (its point of greatest condensation) to 212°	1 in 24
Expansion of water in freezing	1 in 12

TABLE VIII.—QUANTITIES RELATING TO PIPES.

Size of Pipe.	Gallons per foot.	Square feet of surface in one lineal foot.
inches.	gallons.	
½	·0084	—
¾	·0191	·27
1	·0339	·34
1¼	·0529	·43
1½	·0764	·50
2	·1358	·62
2½	·2122	·75
3	·3056	·92
4	·5433	1·17
5	·8490	—
6	1·2226	—
8	2·1762	—
10	3·4010	—
12	4·9	—

If the decimal point is removed one place to the right, the number will be per 10 feet; if point be removed two places to the right, the number will be per 100 feet.

TABLE IX.—WEIGHTS OF ROUND IRON.

(Compiled by Messrs. J. E. & S. Spencer, London, and published in the Correspondence Columns of *The Ironmonger.*)

To arrive at the Weight of a Tube, the difference between the weight of a solid bar of the outer and inner diameter will give the weight.

Example:—A tube 4 inches external diameter, 3½ inches internal ditto (substance of metal ¼ inch.)

Weight of 4 inch iron	41·888
Less weight of 3½ inch iron	32·071
Weight of tube mentioned	9·817

Diam.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.
$\frac{1}{4}$	·164	$\frac{31}{32}$	2·457	$1\frac{11}{16}$	7·455	$2\frac{13}{32}$	15·158	$3\frac{1}{3}$	25·566
$\frac{9}{32}$	·207	1	2·618	$1\frac{23}{32}$	7·734	$2\frac{7}{16}$	15·555	$3\frac{5}{32}$	26·080
$\frac{5}{16}$	·256	$1\frac{1}{32}$	2·784	$1\frac{3}{4}$	8·018	$2\frac{15}{32}$	15·956	$3\frac{3}{16}$	26·599
$\frac{11}{32}$	·309	$1\frac{1}{16}$	2·955	$1\frac{25}{32}$	8·307	$2\frac{1}{2}$	16·362	$3\frac{7}{32}$	27·123
$\frac{3}{8}$	·368	$1\frac{3}{32}$	3·132	$1\frac{13}{16}$	8·601	$2\frac{17}{32}$	16·774	$3\frac{1}{4}$	27·653
$\frac{13}{32}$	·432	$1\frac{1}{8}$	3·313	$1\frac{27}{32}$	8·900	$2\frac{9}{16}$	17·191	$3\frac{9}{32}$	28·187
$\frac{7}{16}$	·501	$1\frac{5}{32}$	3·500	$1\frac{7}{8}$	9·204	$2\frac{19}{32}$	17·613	$3\frac{5}{16}$	28·726
$\frac{15}{32}$	·575	$1\frac{3}{16}$	3·692	$1\frac{29}{32}$	9·513	$2\frac{5}{8}$	18·040	$3\frac{11}{32}$	29·271
$\frac{1}{2}$	·6545	$1\frac{7}{32}$	3·889	$1\frac{15}{16}$	9·828	$2\frac{21}{32}$	18·472	$3\frac{3}{8}$	29·821
$\frac{17}{32}$	·738	$1\frac{1}{4}$	4·091	$1\frac{31}{32}$	10·147	$2\frac{11}{16}$	18·909	$3\frac{13}{32}$	30·375
$\frac{9}{16}$	·828	$1\frac{9}{32}$	4·298	2	10·472	$2\frac{23}{32}$	19·351	$3\frac{7}{16}$	30·935
$\frac{19}{32}$	·923	$1\frac{5}{16}$	4·510	$2\frac{1}{32}$	10·802	$2\frac{3}{4}$	19·799	$3\frac{15}{32}$	31·500
$\frac{5}{8}$	1·023	$1\frac{11}{32}$	4·727	$2\frac{1}{16}$	11·136	$2\frac{25}{32}$	20·251	$3\frac{1}{2}$	32·071
$\frac{21}{32}$	1·128	$1\frac{3}{8}$	4·950	$2\frac{3}{32}$	11·477	$2\frac{13}{16}$	20·709	$3\frac{17}{32}$	32·646
$\frac{11}{16}$	1·237	$1\frac{13}{32}$	5·177	$2\frac{1}{8}$	11·822	$2\frac{27}{32}$	21·172	$3\frac{9}{16}$	33·226
$\frac{23}{32}$	1·352	$1\frac{7}{16}$	5·410	$2\frac{5}{32}$	12·172	$2\frac{7}{8}$	21·639	$3\frac{19}{32}$	33·812
$\frac{3}{4}$	1·473	$1\frac{15}{32}$	5·648	$2\frac{3}{16}$	12·528	$2\frac{29}{32}$	22·112	$3\frac{5}{8}$	34·402
$\frac{25}{32}$	1·598	$1\frac{1}{2}$	5·890	$2\frac{7}{32}$	12·888	$2\frac{15}{16}$	22·590	$3\frac{21}{32}$	34·998
$\frac{13}{16}$	1·728	$1\frac{17}{32}$	6·138	$2\frac{1}{4}$	—	$2\frac{31}{32}$	23·074	$3\frac{11}{16}$	35·599
$\frac{27}{32}$	1·864	$1\frac{9}{16}$	6·392	$2\frac{9}{32}$	13·624	3	23·562	$3\frac{23}{32}$	36·205
$\frac{7}{8}$	2·004	$1\frac{19}{32}$	6·650	$2\frac{5}{16}$	14·000	$3\frac{1}{32}$	24·055	$3\frac{3}{4}$	36·816
$\frac{29}{32}$	2·150	$1\frac{5}{8}$	6·913	$2\frac{11}{32}$	14·381	$3\frac{1}{16}$	24·554	$3\frac{25}{32}$	37·432
$\frac{15}{16}$	2·301	$1\frac{21}{32}$	7·182	$2\frac{3}{8}$	14·767	$3\frac{3}{32}$	25·058	$3\frac{13}{16}$	38·053

TABLE IX.—*Continued.*

Diam.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.
$3\frac{27}{32}$	38·679	$4\frac{7}{8}$	62·218	$5\frac{29}{32}$	91·326	$6\frac{15}{16}$	126·001	$7\frac{31}{32}$	166·246
$3\frac{7}{8}$	39·311	$4\frac{29}{32}$	63·019	$5\frac{15}{16}$	92·295	$6\frac{31}{32}$	127·139	8	167·552
$3\frac{29}{32}$	39·948	$4\frac{15}{16}$	63·824	$5\frac{31}{32}$	93·267	7	128·282	$8\frac{1}{32}$	168·864
$3\frac{15}{16}$	40·589	$4\frac{31}{32}$	64·634	6	94·248	$7\frac{1}{32}$	129·430	$8\frac{1}{16}$	170·180
$3\frac{31}{32}$	41·236	5	65·450	$6\frac{1}{32}$	95·232	$7\frac{1}{16}$	130·583	$8\frac{3}{32}$	171·502
4	41·888	$5\frac{1}{32}$	66·271	$6\frac{1}{16}$	96·222	$7\frac{3}{32}$	131·741	$8\frac{1}{8}$	172·829
$4\frac{1}{32}$	42·545	$5\frac{1}{16}$	67·096	$6\frac{3}{32}$	97·216	$7\frac{1}{8}$	132·904	$8\frac{5}{32}$	174·161
$4\frac{1}{16}$	43·207	$5\frac{3}{32}$	67·927	$6\frac{1}{8}$	98·216	$7\frac{5}{32}$	134·072	$8\frac{3}{16}$	175·498
$4\frac{3}{32}$	43·875	$5\frac{1}{8}$	68·763	$6\frac{5}{32}$	99·221	$7\frac{3}{16}$	135·246	$8\frac{7}{32}$	176·840
$4\frac{1}{8}$	44·547	$5\frac{5}{32}$	69·605	$6\frac{3}{16}$	100·231	$7\frac{7}{32}$	136·425	$8\frac{1}{4}$	178·188
$4\frac{5}{32}$	45·224	$5\frac{3}{16}$	70·451	$6\frac{7}{32}$	101·246	$7\frac{1}{4}$	137·609	$8\frac{9}{32}$	179·540
$4\frac{3}{16}$	45·907	$5\frac{7}{32}$	71·302	$6\frac{1}{4}$	102·266	$7\frac{9}{32}$	138·797	$8\frac{5}{16}$	180·898
$4\frac{7}{32}$	46·595	$5\frac{1}{4}$	72·159	$6\frac{9}{32}$	103·291	$7\frac{5}{16}$	139·991	$8\frac{11}{32}$	182·260
$4\frac{1}{4}$	47·288	$5\frac{9}{32}$	73·020	$6\frac{5}{16}$	104·321	$7\frac{11}{32}$	141·190	$8\frac{3}{8}$	183·628
$4\frac{9}{32}$	47·886	$5\frac{5}{16}$	73·887	$6\frac{11}{32}$	105·357	$7\frac{3}{8}$	142·395	$8\frac{13}{32}$	185·001
$4\frac{5}{16}$	48·689	$5\frac{11}{32}$	74·759	$6\frac{3}{8}$	106·397	$7\frac{13}{32}$	143·604	$8\frac{7}{16}$	186·379
$4\frac{11}{32}$	49·397	$5\frac{3}{8}$	75·636	$6\frac{13}{32}$	107·443	$7\frac{7}{16}$	144·818	$8\frac{15}{32}$	187·762
$4\frac{3}{8}$	50·110	$5\frac{13}{32}$	76·518	$6\frac{7}{16}$	108·494	$7\frac{15}{32}$	146·038	$8\frac{1}{2}$	189·150
$4\frac{13}{32}$	50·829	$5\frac{7}{16}$	77·405	$6\frac{15}{32}$	109·549	$7\frac{1}{2}$	147·263	$8\frac{17}{32}$	190·544
$4\frac{7}{16}$	51·552	$5\frac{15}{32}$	78·297	$6\frac{1}{2}$	110·611	$7\frac{17}{32}$	148·492	$8\frac{9}{16}$	191·942
$4\frac{15}{32}$	52·281	$5\frac{1}{2}$	79·194	$6\frac{17}{32}$	111·677	$7\frac{9}{16}$	149·727	$8\frac{19}{32}$	193·346
$4\frac{1}{2}$	53·016	$5\frac{17}{32}$	80·097	$6\frac{9}{16}$	112·748	$7\frac{19}{32}$	150·967	$8\frac{5}{8}$	194·754
$4\frac{17}{32}$	53·753	$5\frac{9}{16}$	81·005	$6\frac{19}{32}$	113·824	$7\frac{5}{8}$	152·212	$8\frac{21}{32}$	196·168
$4\frac{9}{16}$	54·497	$5\frac{19}{32}$	81·917	$6\frac{5}{8}$	114·906	$7\frac{21}{32}$	153·462	$8\frac{11}{16}$	197·587
$4\frac{19}{32}$	55·246	$5\frac{5}{8}$	82·835	$6\frac{21}{32}$	115·992	$7\frac{11}{16}$	154·717	$8\frac{23}{32}$	199·011
$4\frac{5}{8}$	56·000	$5\frac{21}{32}$	83·758	$6\frac{11}{16}$	117·084	$7\frac{23}{32}$	155·978	$8\frac{3}{4}$	200·441
$4\frac{21}{32}$	56·760	$5\frac{11}{16}$	84·886	$6\frac{23}{32}$	118·181	$7\frac{3}{4}$	157·244	$8\frac{25}{32}$	201·875
$4\frac{11}{16}$	57·524	$5\frac{23}{32}$	85·819	$6\frac{3}{4}$	119·283	$7\frac{25}{32}$	158·514	$8\frac{13}{16}$	203·314
$4\frac{23}{32}$	58·294	$5\frac{3}{4}$	86·558	$6\frac{25}{32}$	120·390	$7\frac{13}{16}$	159·790	$8\frac{27}{32}$	204·759
$4\frac{3}{4}$	59·069	$5\frac{25}{32}$	87·501	$6\frac{13}{16}$	121·502	$7\frac{27}{32}$	161·071	$8\frac{7}{8}$	206·208
$4\frac{25}{32}$	59·848	$5\frac{13}{16}$	88·450	$6\frac{27}{32}$	122·619	$7\frac{7}{8}$	162·357	$8\frac{29}{32}$	207·663
$4\frac{13}{16}$	60·633	$5\frac{27}{32}$	89·403	$6\frac{7}{8}$	123·741	$7\frac{29}{32}$	163·648	$8\frac{15}{16}$	209·123
$4\frac{27}{32}$	61·423	$5\frac{7}{8}$	90·362	$6\frac{29}{32}$	124·869	$7\frac{15}{16}$	164·944	$8\frac{31}{32}$	210·588

TABLE IX.—*Continued.*

Diam.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.	Diam.	Weight.
9	212·058	$9\frac{5}{8}$	242·533	$10\frac{1}{4}$	275·054	$10\frac{27}{32}$	307·843	$11\frac{7}{16}$	342·477
$9\frac{1}{32}$	213·533	$9\frac{21}{32}$	244·111	$10\frac{9}{32}$	276·733	$10\frac{7}{8}$	309·619	$11\frac{15}{32}$	344·351
$9\frac{1}{16}$	215·013	$9\frac{11}{16}$	245·693	$10\frac{5}{16}$	278·418	$10\frac{29}{32}$	311·401	$11\frac{1}{2}$	346·231
$9\frac{3}{32}$	216·499	$9\frac{23}{32}$	247·281	$10\frac{11}{32}$	280·108	$10\frac{15}{16}$	313·188	$11\frac{17}{32}$	348·115
$9\frac{1}{8}$	217·989	$9\frac{3}{4}$	248·874	$10\frac{3}{8}$	281·803	$10\frac{31}{32}$	314·981	$11\frac{9}{16}$	350·004
$9\frac{5}{32}$	219·485	$9\frac{25}{32}$	250·472	$10\frac{13}{32}$	283·503	11	316·778	$11\frac{19}{32}$	351·899
$9\frac{3}{16}$	220·986	$9\frac{13}{16}$	252·218	$10\frac{7}{16}$	285·209	$11\frac{1}{32}$	318·580	$11\frac{5}{8}$	353·798
$9\frac{7}{32}$	222·492	$9\frac{27}{32}$	253·683	$10\frac{15}{32}$	286·957	$11\frac{1}{16}$	320·388	$11\frac{21}{32}$	355·703
$9\frac{1}{4}$	224·003	$9\frac{7}{8}$	255·296	$10\frac{1}{2}$	288·635	$11\frac{3}{32}$	322·201	$11\frac{11}{16}$	357·613
$9\frac{9}{32}$	225·519	$9\frac{29}{32}$	256·914	$10\frac{17}{32}$	290·355	$11\frac{1}{8}$	324·018	$11\frac{23}{32}$	359·528
$9\frac{5}{16}$	227·040	$9\frac{15}{16}$	258·538	$10\frac{9}{16}$	292·081	$11\frac{5}{32}$	325·841	$11\frac{3}{4}$	361·448
$9\frac{11}{32}$	228·566	$9\frac{31}{32}$	260·166	$10\frac{19}{32}$	293·812	$11\frac{3}{16}$	327·669	$11\frac{25}{32}$	363·373
$9\frac{3}{8}$	230·098	10	261·800	$10\frac{5}{8}$	295·548	$11\frac{7}{32}$	329·502	$11\frac{13}{16}$	365·303
$9\frac{13}{32}$	231·634	$10\frac{1}{32}$	263·439	$10\frac{21}{32}$	297·289	$11\frac{1}{4}$	331·341	$11\frac{27}{32}$	367·238
$9\frac{7}{16}$	233·176	$10\frac{1}{16}$	265·083	$10\frac{11}{16}$	298·035	$11\frac{9}{32}$	333·184	$11\frac{7}{8}$	369·179
$9\frac{15}{32}$	234·783	$10\frac{3}{32}$	266·732	$10\frac{23}{32}$	300·786	$11\frac{5}{16}$	335·032	$11\frac{29}{32}$	371·125
$9\frac{1}{2}$	236·275	$10\frac{1}{8}$	268·385	$10\frac{3}{4}$	302·543	$11\frac{11}{32}$	336·886	$11\frac{15}{16}$	373·075
$9\frac{17}{32}$	237·831	$10\frac{5}{32}$	270·045	$10\frac{25}{32}$	304·304	$11\frac{3}{8}$	338·745	$11\frac{31}{32}$	375·031
$9\frac{9}{16}$	239·394	$10\frac{3}{16}$	271·710	$10\frac{13}{16}$	306·071	$11\frac{13}{32}$	340·608	12	376·992
$9\frac{19}{32}$	240·961	$10\frac{7}{32}$	273·379						

TABLE X CORRESPONDING DEGREES OF THE CENTIGRADE AND FAHRENHEIT THERMOMETERS.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
+ 220 =	+ 428·0	+ 82 =	+ 179·6	+ 41 =	+ 105·8	+ 0 =	+ 32
215 =	419·0	81 =	177·8	40 =	104	— 1 =	30·2
210 =	410·0	80 =	176	39 =	102·2	2 =	28·4
205 =	401·0	79 =	174·2	38 =	100·4	3 =	26·6
200 =	392·0	78 =	172·4	37 =	98·6	4 =	24·8
195 =	383·0	77 =	170·6	36 =	96·8	5 =	23
190 =	374·0	76 =	168·8	35 =	95	6 =	21·2
185 =	365·0	75 =	167	34 =	93·2	7 =	19·4
180 =	356·0	74 =	165·2	33 =	91·4	8 =	17·6
175 =	347·0	73 =	163·4	32 =	89·6	9 =	15·8
170 =	338·0	72 =	161·6	31 =	87·8	10 =	14
165 =	329·0	71 =	159·8	30 =	86	11 =	12·2
160 =	320·0	70 =	158	29 =	84·2	12 =	10·4
155 =	311·0	69 =	156·2	28 =	82·4	13 =	8·6
150 =	302·0	68 =	154·4	27 =	80·6	14 =	6·8
145 =	293·0	67 =	152·6	26 =	78·8	15 =	5
140 =	284·0	66 =	150·8	25 =	77	16 =	3·2
135 =	275·0	65 =	149	24 =	75·2	17 =	1·4
130 =	266·0	64 =	147·2	23 =	73·4	18 =	— 0·4
125 =	257·0	63 =	145·4	22 =	71·6	19 =	2·2
120 =	248·0	62 =	143·6	21 =	69·8	20 =	4
115 =	239·0	61 =	141·8	20 =	68	21 =	5·8
110 =	230·0	60 =	140	19 =	66·2	22 =	7·6
100 =	212	59 =	138·2	18 =	64·4	23 =	9·4
99 =	210·2	58 =	136·4	17 =	62·6	24 =	11·2
98 =	208·4	57 =	134·6	16 =	60·8	25 =	13
97 =	206·6	56 =	132·8	15 =	59	26 =	14·8
96 =	204·8	55 =	131	14 =	57·2	27 =	16·6
95 =	203	54 =	129·2	13 =	55·4	28 =	18·4
94 =	201·2	53 =	127·4	12 =	53·6	29 =	20·2
93 =	199·4	52 =	125·6	11 =	51·8	30 =	22
92 =	197·6	51 =	123·8	10 =	50	31 =	23·8
91 =	195·8	50 =	122	9 =	48·2	32 =	25·6
90 =	194	49 =	120·2	8 =	46·4	33 =	27·4
89 =	192·2	48 =	118·4	7 =	44·6	34 =	29·2
88 =	190·4	47 =	116·6	6 =	42·8	35 =	31
87 =	188·6	46 =	114·8	5 =	41	36 =	32·8
86 =	186·8	45 =	113	4 =	39·2	37 =	34·6
85 =	185	44 =	111·2	3 =	37·4	38 =	36·4
84 =	183·2	43 =	109·4	2 =	35·6	39 =	38·2
83 =	181·4	42 =	107·6	1 =	33·8	40 =	40

The following rule can be adopted for converting one thermometric scale into another.

Centigrade degrees ÷ 5 × 9 + 32 = Fahrenheit degrees.
,, ,, ÷ 5 × 4 = Réaumur ,,
Fahrenheit ,, − 32 ÷ 9 × 5 = Centigrade ,,
,, ,, − 32 ÷ 9 × 4 = Réaumur ,,
Réaumur ,, ÷ 4 × 9 + 32 = Fahrenheit ,,
,, ,, ÷ 4 × 5 = Centigrade ,,

TABLE XI.—SPECIFIC GRAVITIES OF SOLIDS AT 39·2° F. (4° C.) WATER AT 39·2° F. = 1·000.

Aluminium	2·670	Manganese	8·013
Amber	1·080	Molybdenum	8·620
Anthracite	1·800	Nickel	8·820
Antimony	6·710	Obsidian	2·300
Bismuth	9·799	Osmium	21·400
Brass	8·300	Palladium	11·800
Bronze	8·800	Phosphorus	1·830
Cadmium	8·604	Platinum	21·530
Calcium	1·578	Potassium	0·865
Charcoal, oak	1·570	Rhodium	12·100
,, beech	0·518	Rubidium	1·520
,, birch	0·364	Ruthenium	11·400
Coal	1·330	Silver	10·530
Coke	1·865	Sodium	0·972
Copper	8·950	Steatite	2·800
Coral	2·680	Steel	7·810
Glass, flint	3·330	Sulphur	2·050
Gold	19·340	Tellurium	6·650
Graphite	2·300	Tin	7·292
Gun-metal	8·460	Titanium	5·300
Ice	0·920	Tungsten	17·600
Iridium	21·150	Uranium	18·400
Iron, cast	7·210	Wood, ash	0·845
,, wrought	7·840	,, beech	0·852
Ivory	1·920	,, elm	0·800
Lead	11·360	,, cork	0·240
Lime	3·180	Zinc	7·146
Lithium	0·593	Zircon	4·300
Magnesium	1·743		

TABLE XII.—SPECIFIC GRAVITIES OF LIQUIDS. WATER AT 39·2° F. = 1·000.

Ammonia (solution)	0·875	Naphtha	0·860 to 0·900
,, (liquid)	0·730	Oil, almond (59° F.)	0·918
Beer	1·023 to 1·034	,, castor	0·969
Benzol (C_6H_6)	0·850	,, cod-liver	0·928
Bromine (at 32° F.)	3·187	,, linseed (53° F.)	0·939
Cyanogen (liquid)	0·866	,, olive	0·918
Essential oil of bitter almonds	1·049	Tar	1·120 to 1·150
,, ,, turpentine	0·864	Water, distilled	1·000
Hydrochloric acid (liquid)	1·270	,, rain	1·001
,, ,, (solution)	1·210	,, sea	1·026
Mercury (at 32° F.)	13·596	Wine	0·990 to 1·038
Milk	1·030		

Table XIII.—Specific Gravities of Gases at 39·2° F. Barometer = 29·9 Inches.

	Air = 1·000.	H = 1·0.
Air	1·000	14·40
Aqueous vapour	0·633	..
Ammonia	0·589	8·50
Azote	0·972	..
Carbonic acid	1·529	22·80
,, oxide	0·967	14·00
Carburetted hydrogen, heavy	0·978	14·00
,, ,, light	0·557	8·00
Chlorine	2·470	35·50
Coal gas, about	0·500	..
Hydrochloric acid	1·247	18·25
Hydrogen	0·069	1·00
Nitric oxide	1·039	15·00
Nitrous ,,	1·527	22·00
Nitrogen	0·971	14·00
Oxygen	1·105	16·00
Sulphurous acid	2·247	32·00

Table XIV.—Linear Expansion of Metals by 180° of Heat, that is from 32° to 212° Fahr. Length of a Bar at 212°, whose Length at 32° is 1·000000.

Bismuth	1·00139167	Pewter, fine	1·00228300
Brass	1·00185540	Platinum	1·00085655
Copper	1·00172244	Silver	1·00190868
Gold	1·00151361	Solder (lead 2 + tin 1)	1·00250800
Iron	1·00125833	Spelter (brass 2 + zinc 1)	1·00205800
,, soft forged	1·00122045	Steel, untempered	1·00107875
,, round, wire-drawn	1·00123504	,, tempered yellow	1·00123956
,, cast	1·00110940	Tin, English	1·00217298
Lead	1·00286700	Zinc	1·00294200

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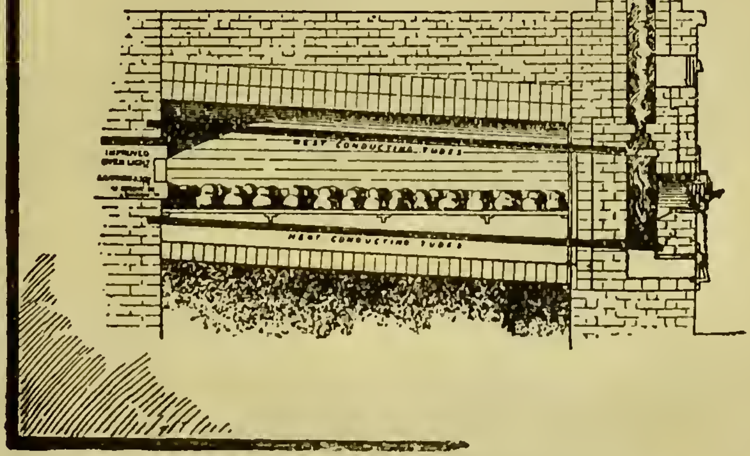

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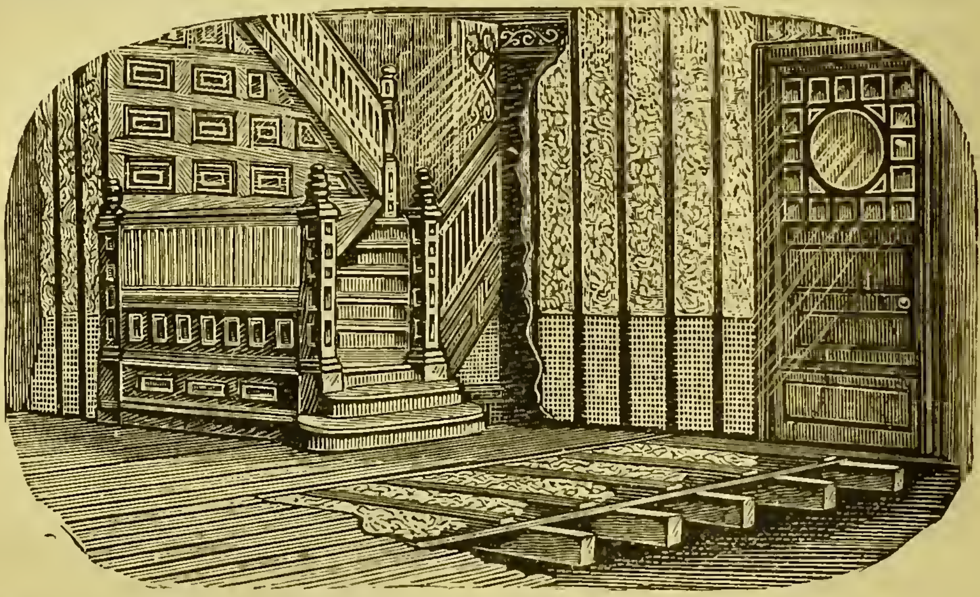

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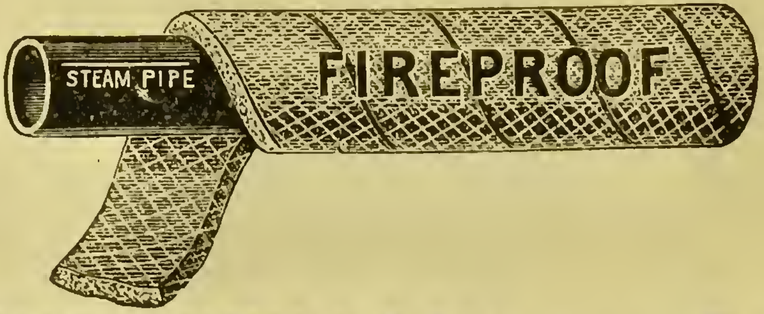

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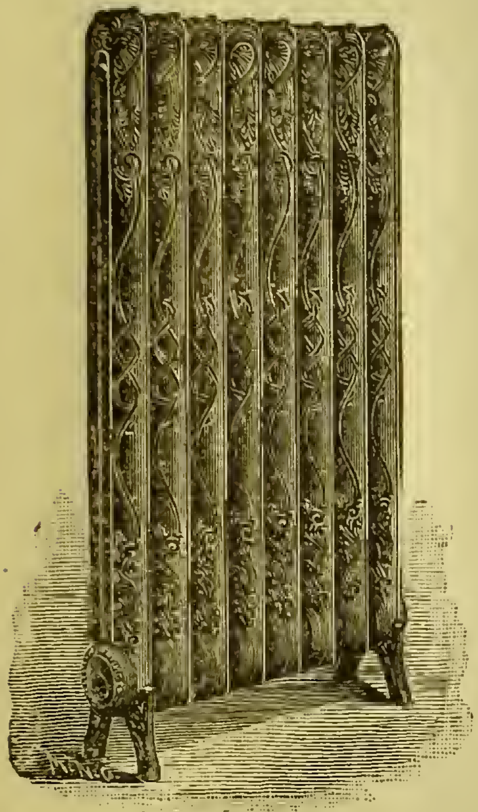

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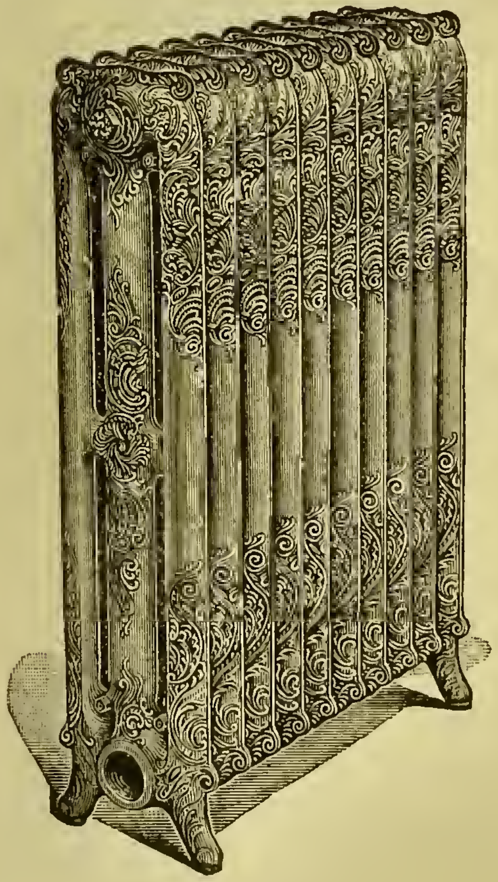

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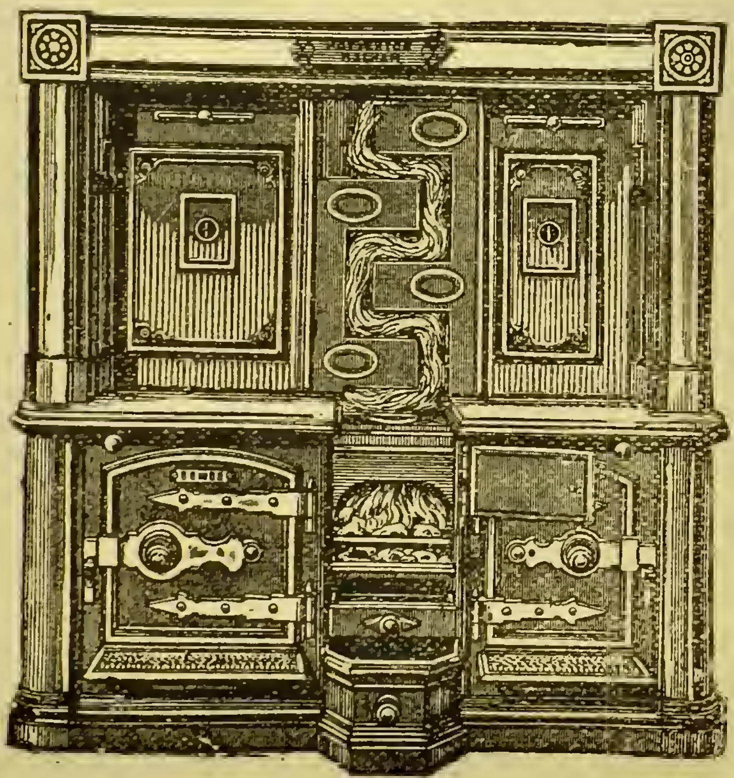

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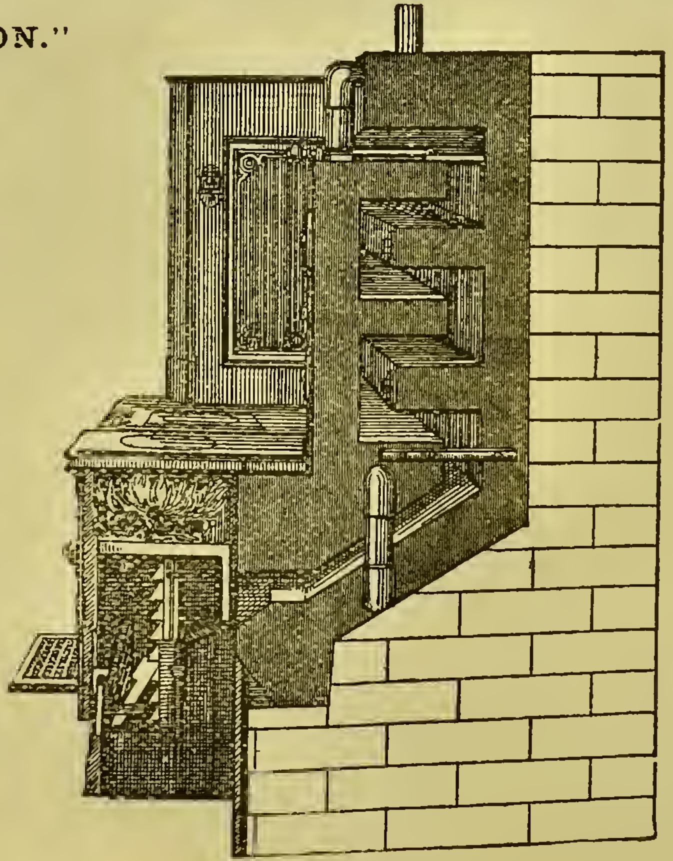

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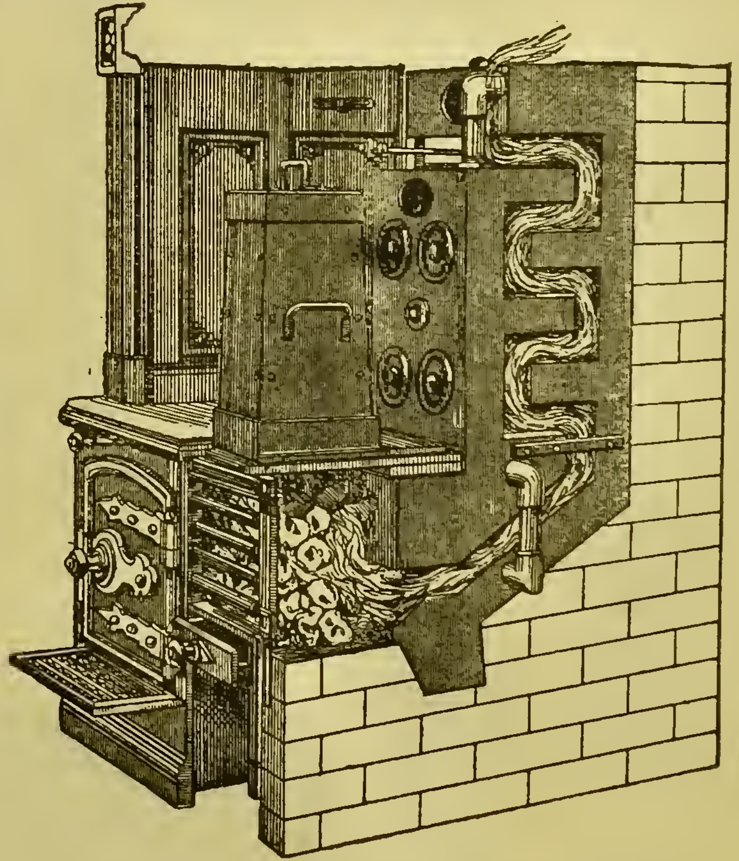

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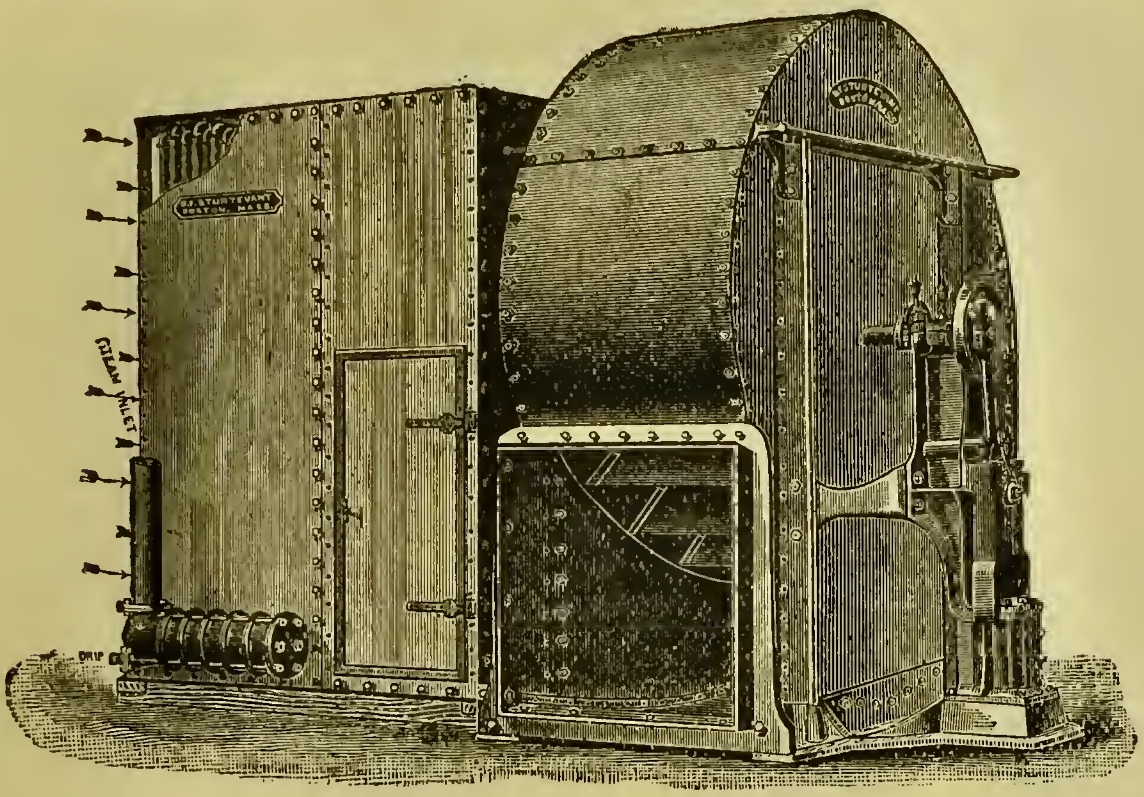

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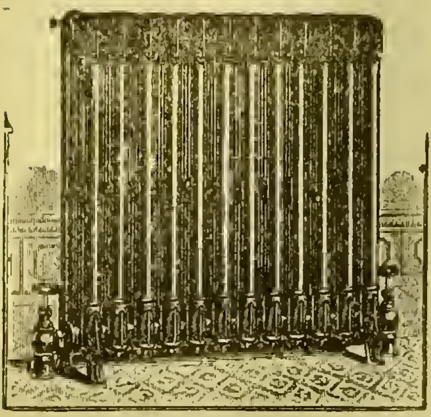

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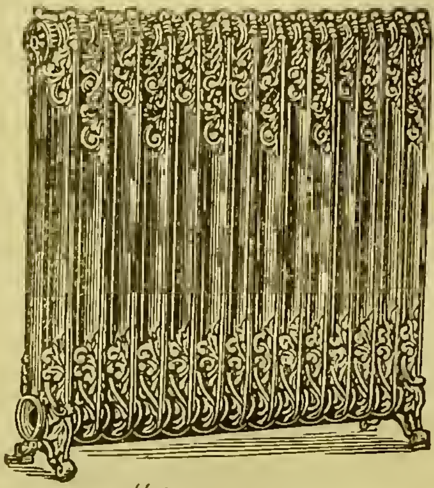

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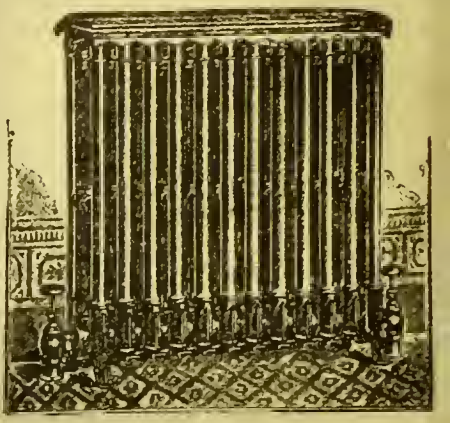

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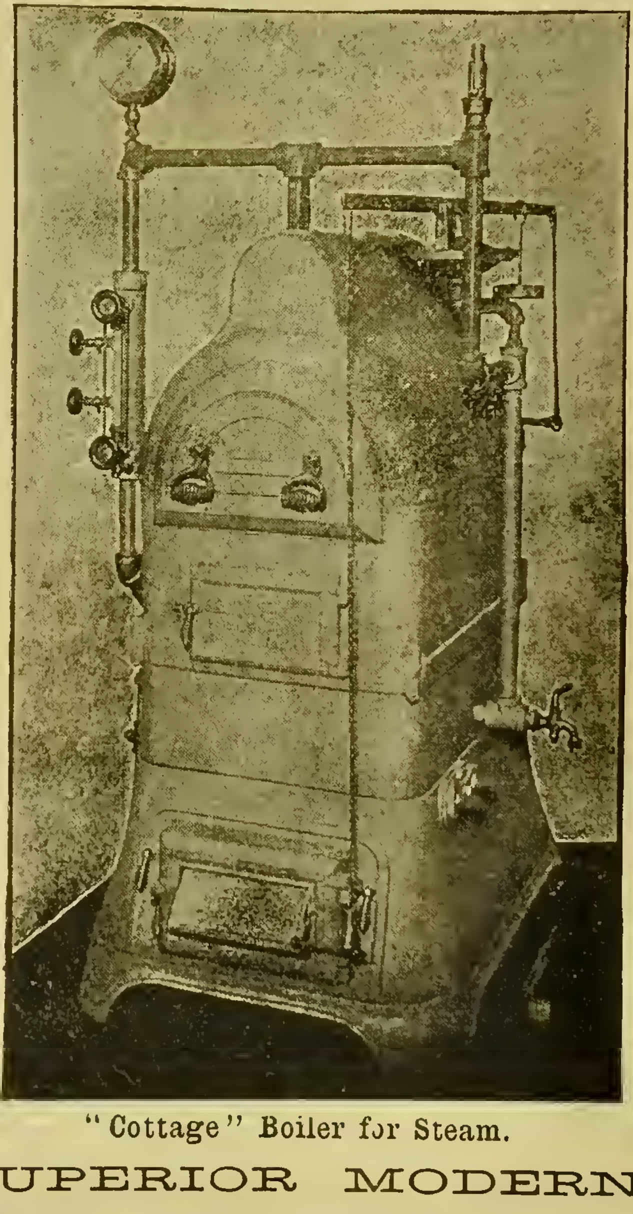

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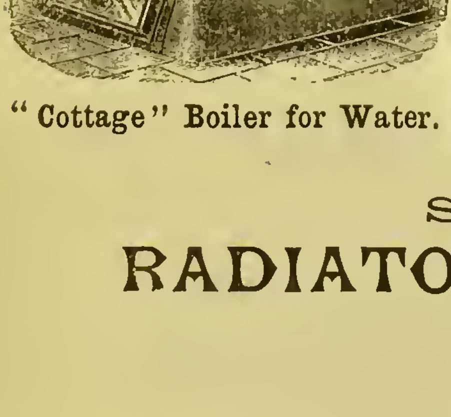

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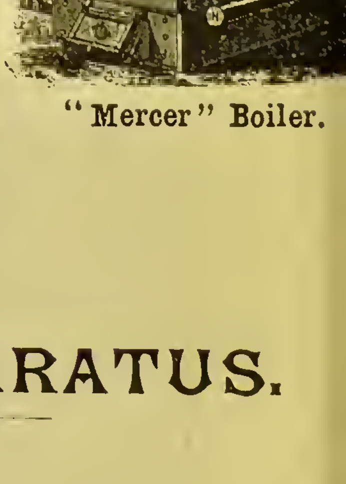

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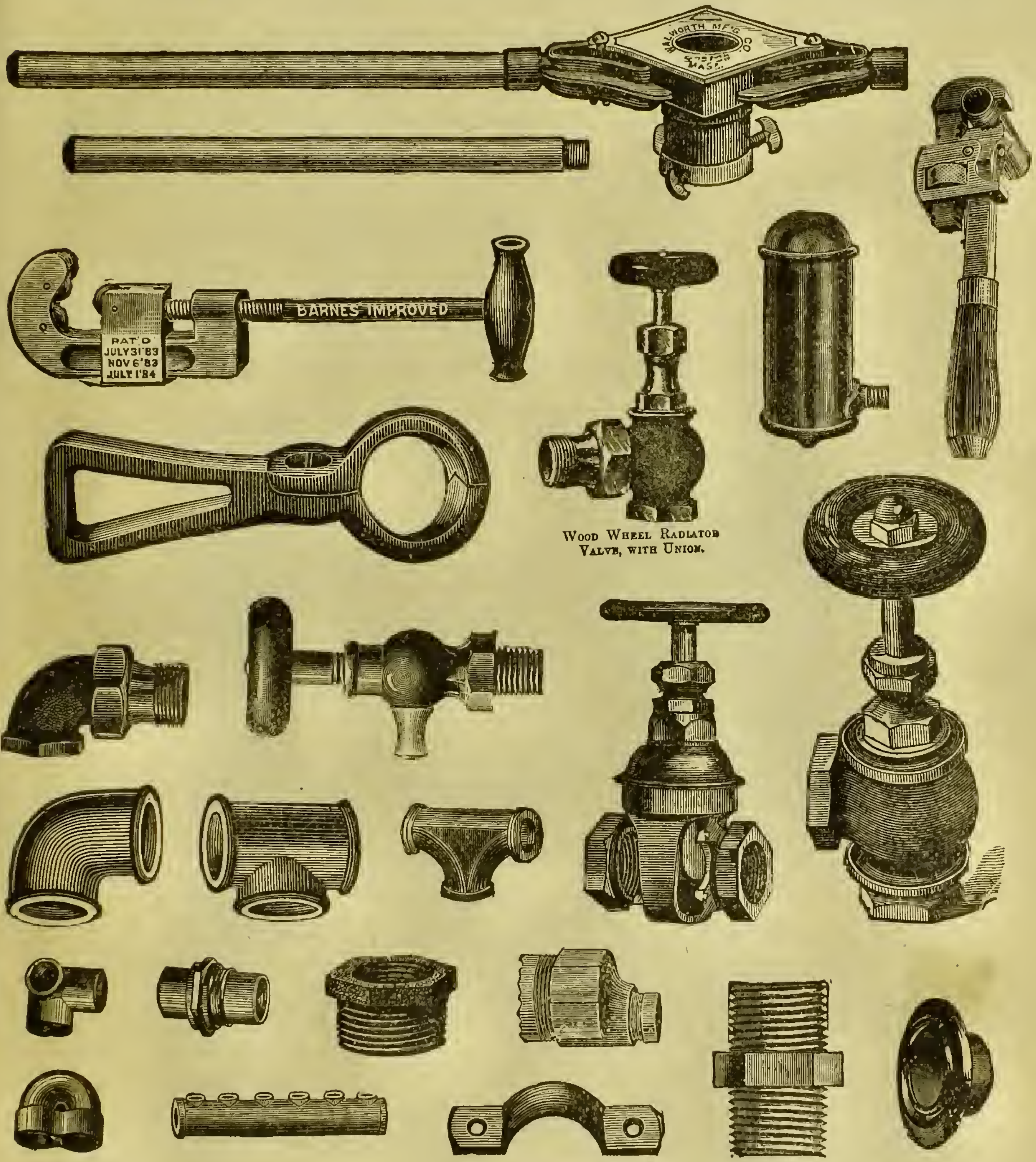
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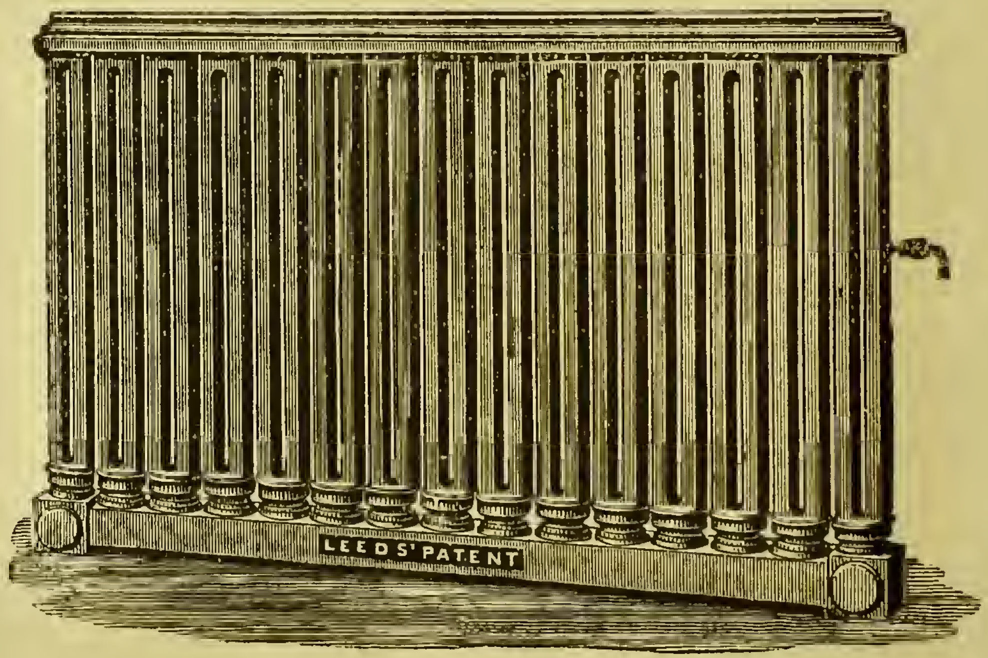

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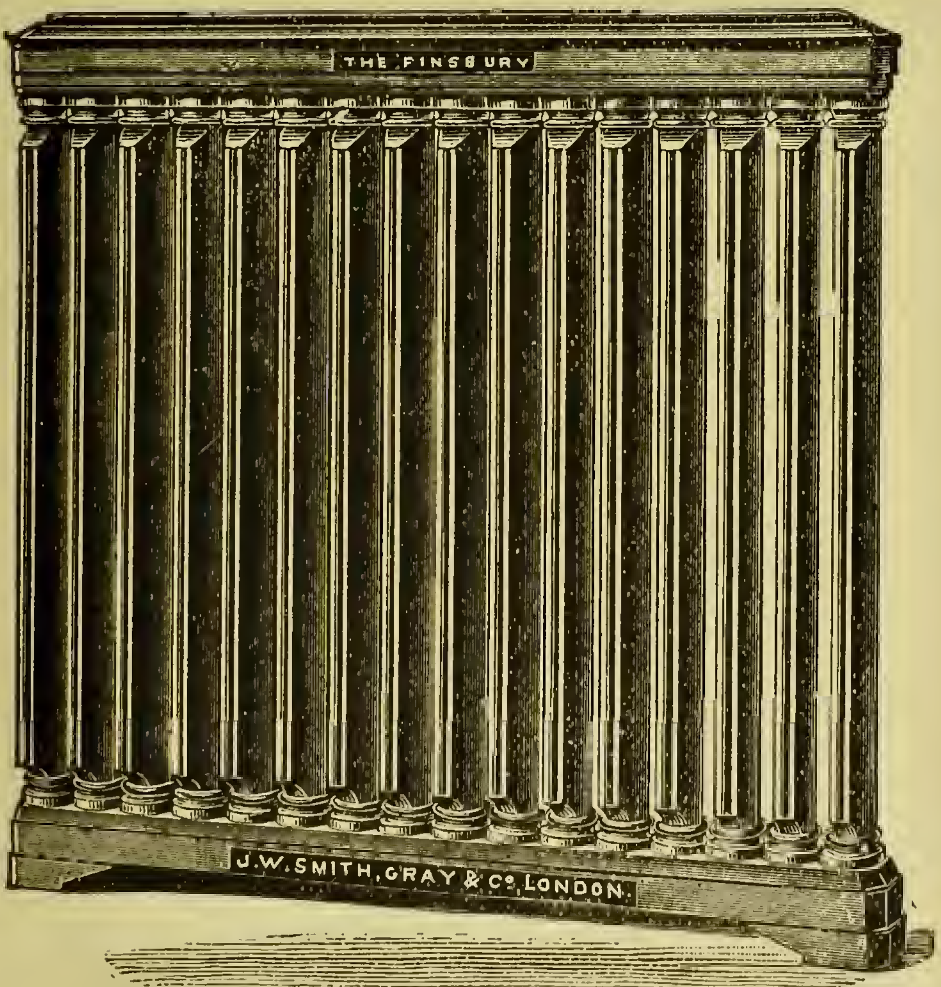

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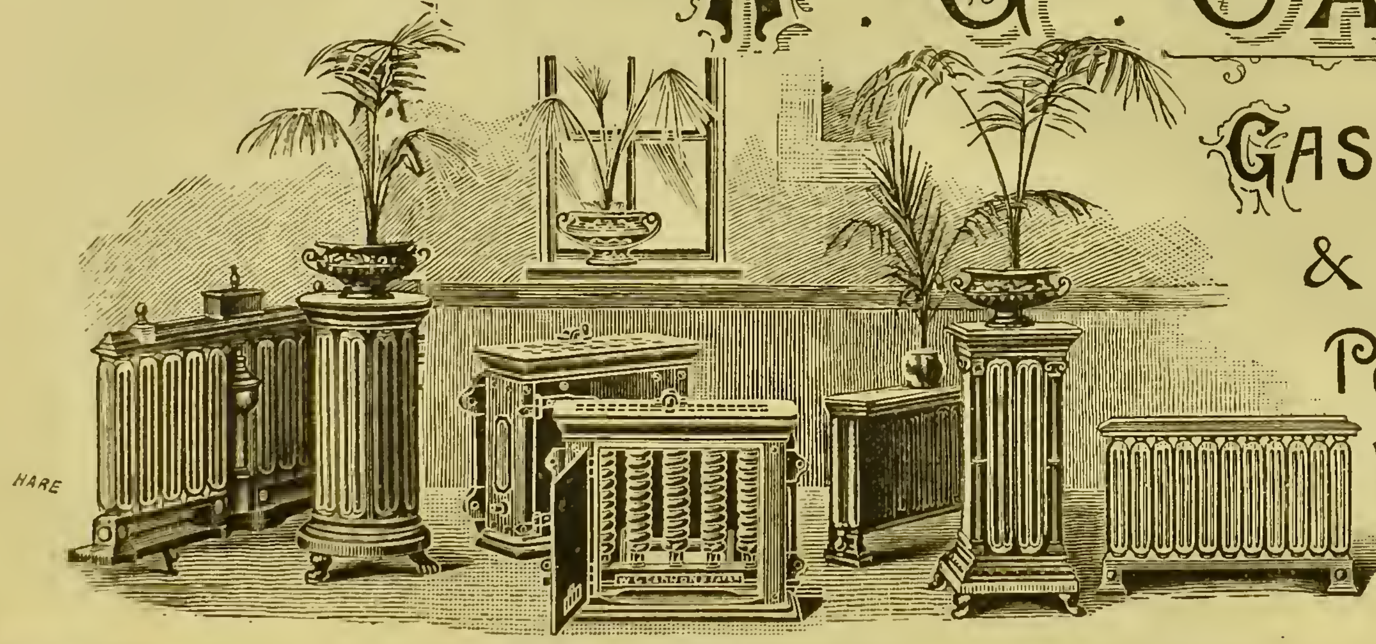

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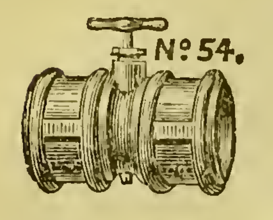

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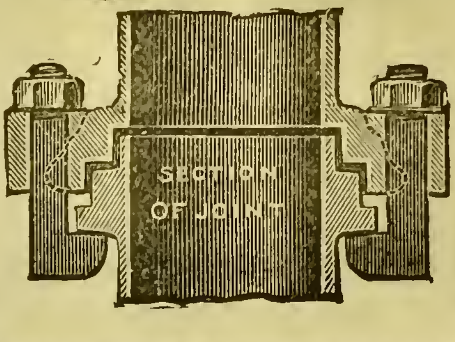

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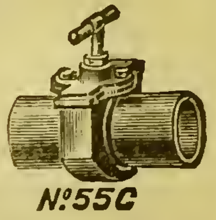

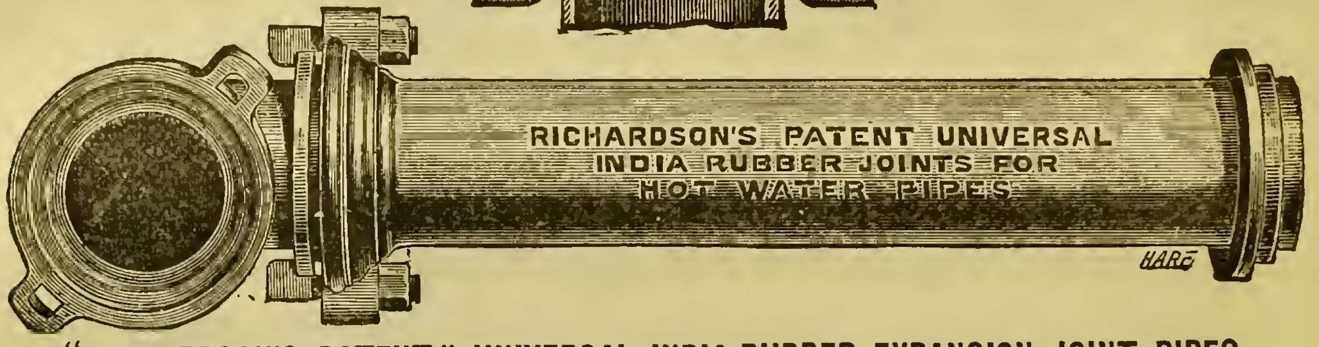
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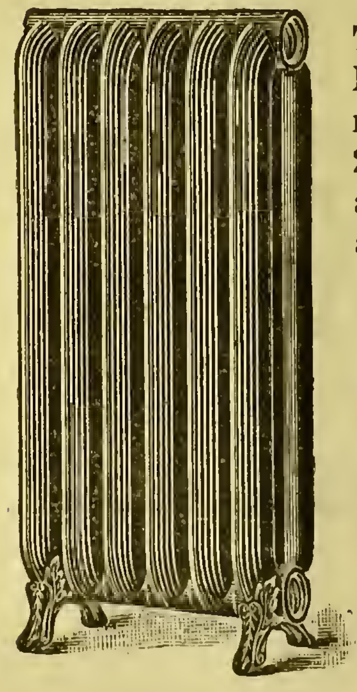

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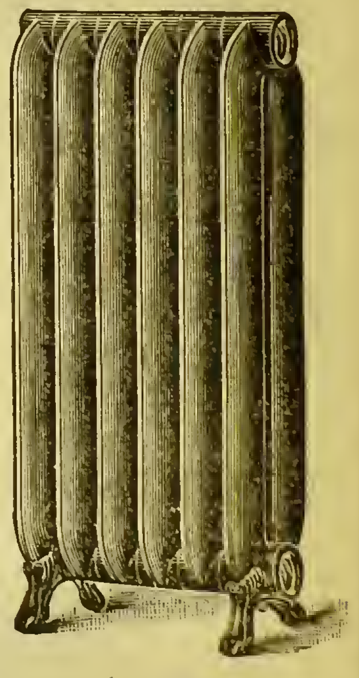

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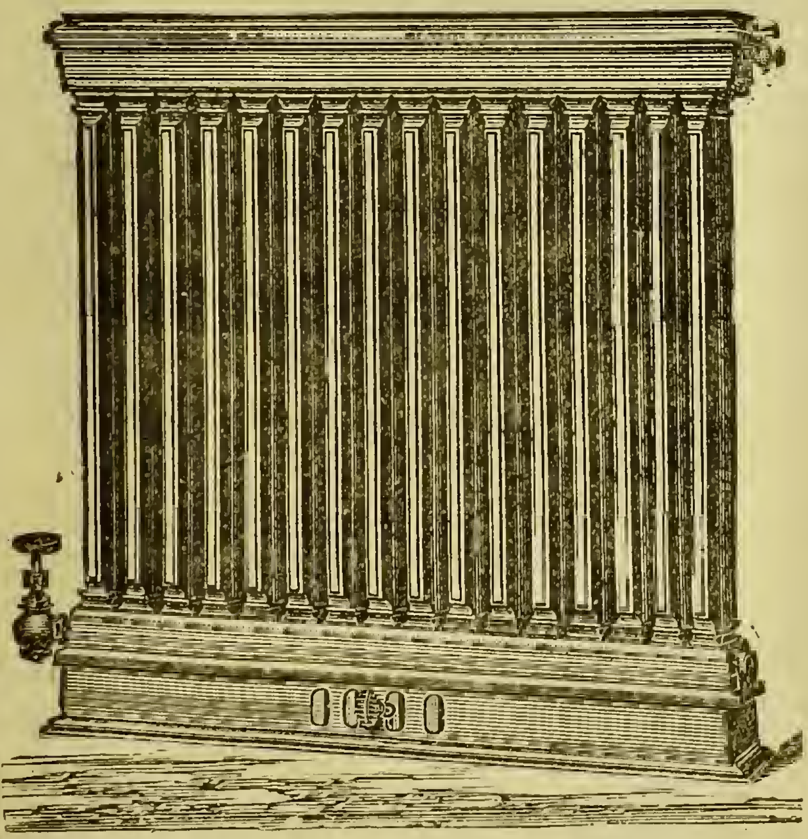

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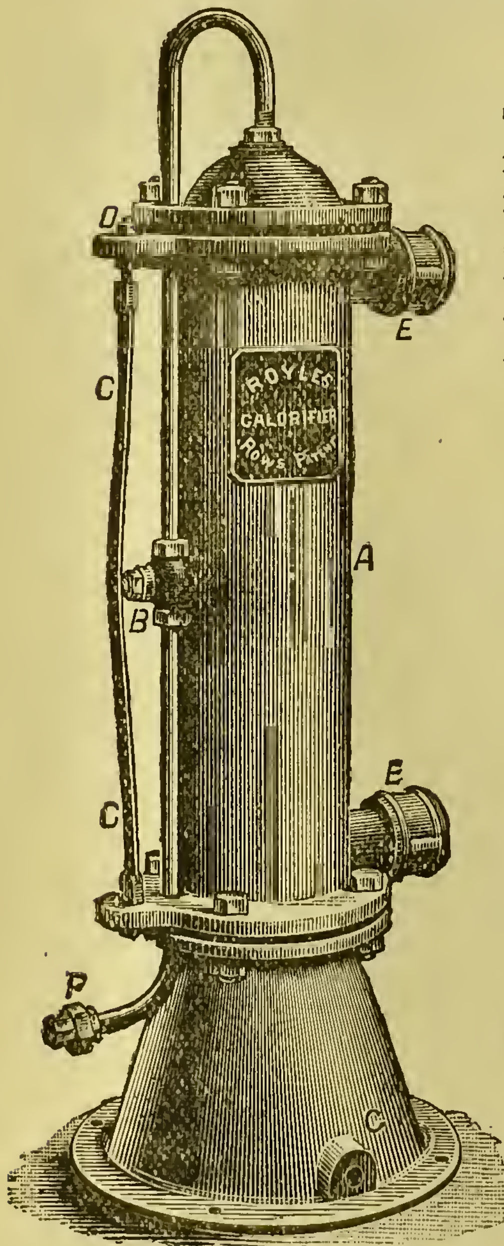

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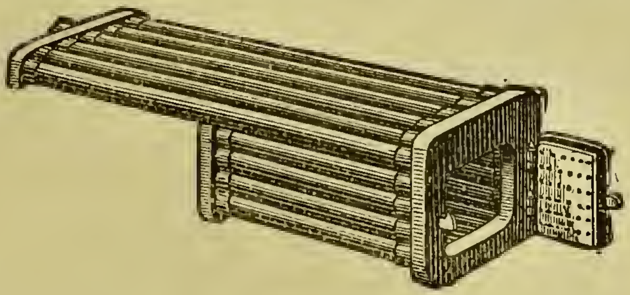

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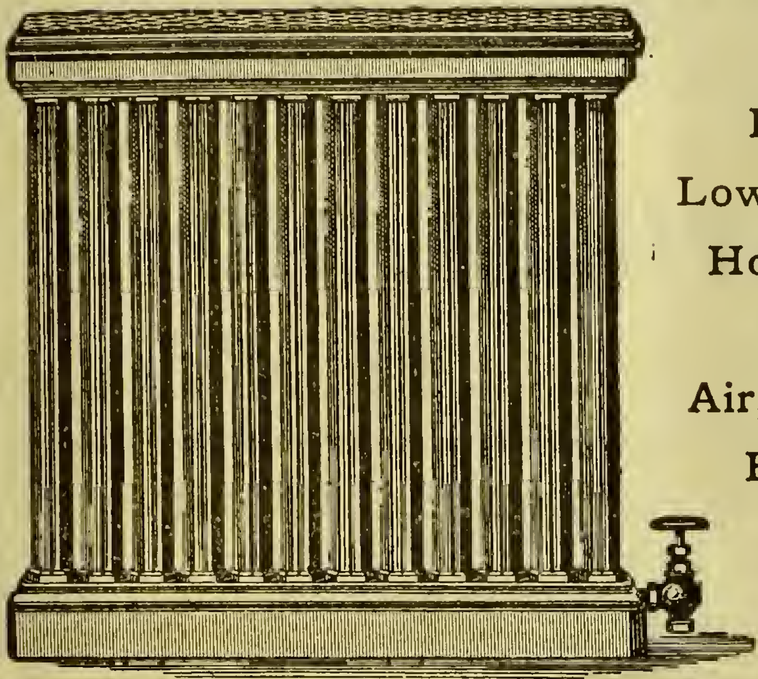

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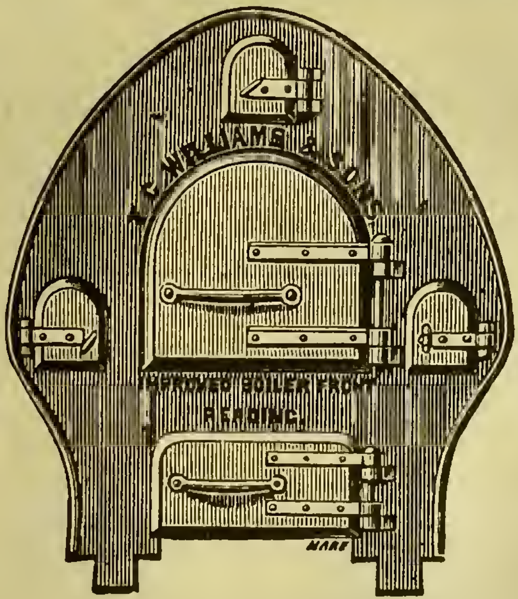

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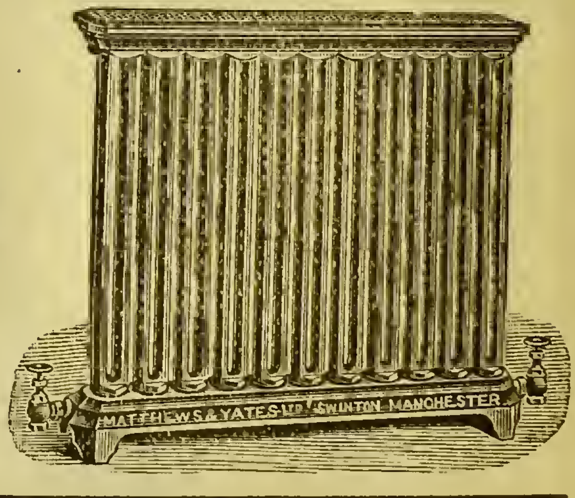
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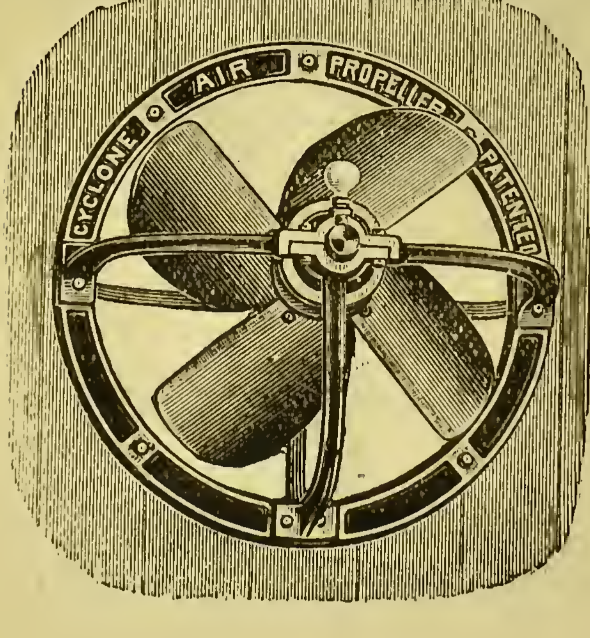

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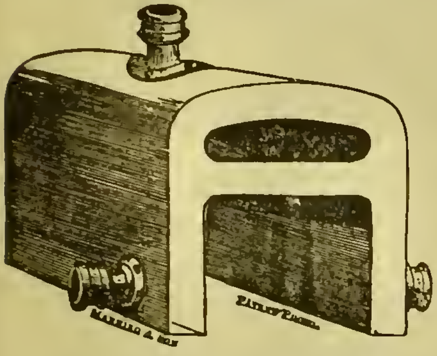

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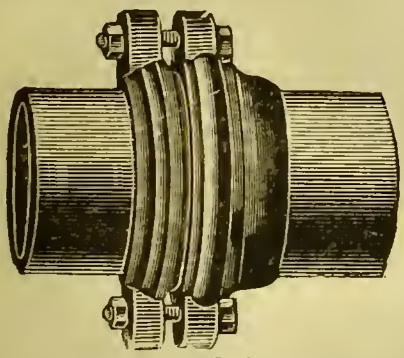

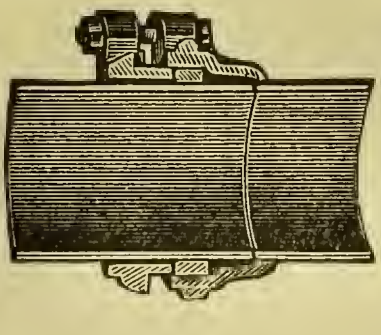

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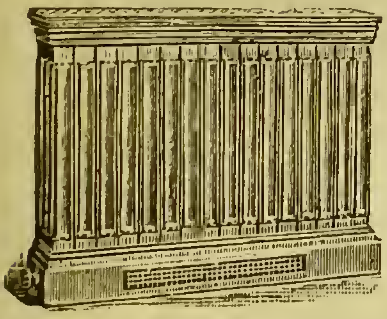

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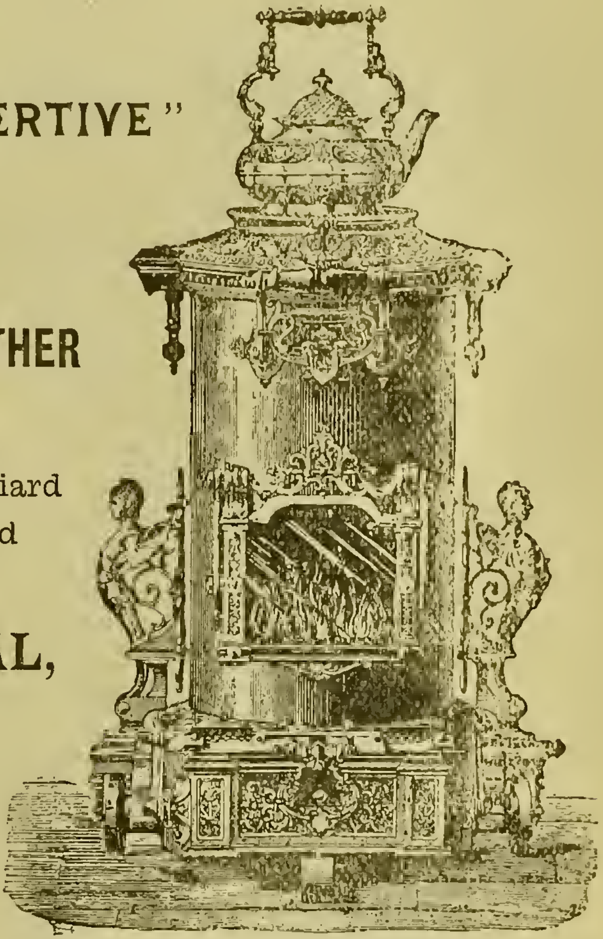

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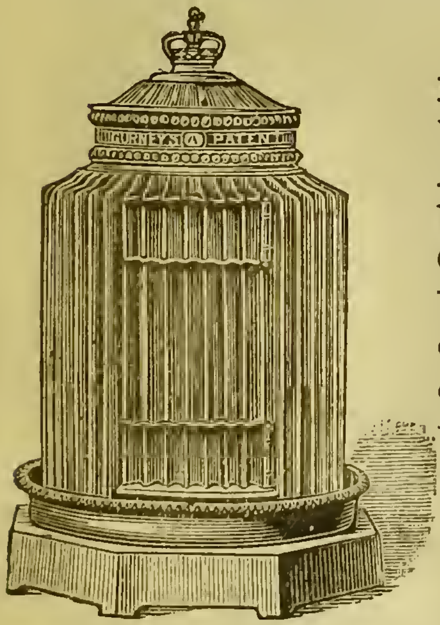

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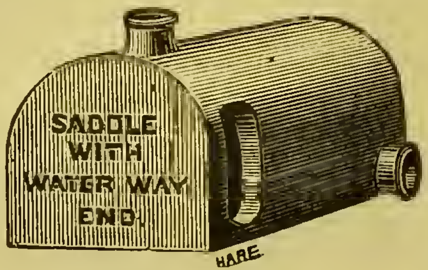
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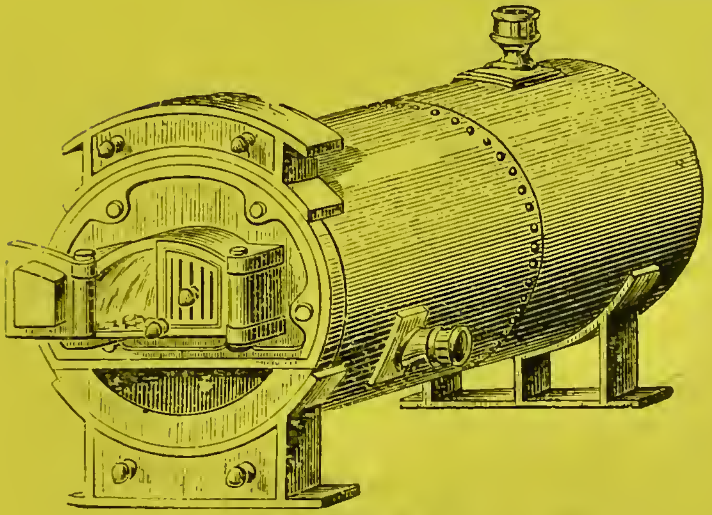

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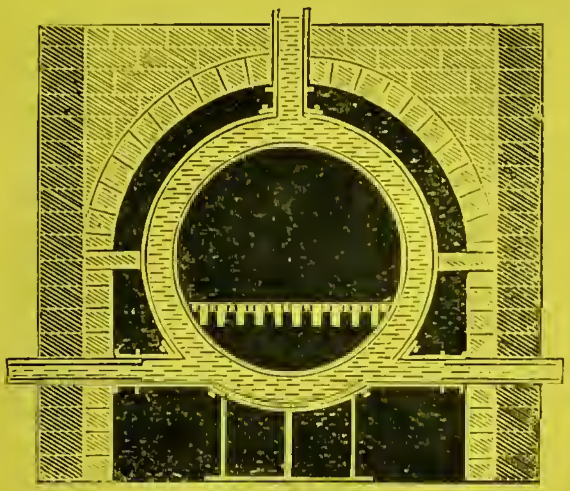

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